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DIRECT CURRENT POWER TRANSMISSION.

BY REAR ADMIRAL S. M. ROBINSON, U. S. N., MEMBER.*

Admiral Robinson needs no introduction to the members of this Society. For many years, his keen mind and sound judgment have profoundly influenced the radical and progressive development of modern Naval engineering. It is a pleasure, therefore, to present this article from his hand as the first of a series of three which will appear in successive issues of the JOURNAL. *While each is complete in itself, the trilogy will deal with a new and revolutionary method of electrical power transmission made possible by electron tubes. Radical and amazing in its departure from the accepted method in general use today, only the possession of the most outstanding advantages would justify the wide obsolescence that its prompt acceptance by industry might entail. Still, when fully developed, it seems probable that the method may have such advantages, and the author points them out in an authoritative and informative manner.*

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For many years we have been accustomed to thinking of alternating current when we think of power transmission; and also when power utilization by variable speed motors is concerned, we have generally thought of direct current. The developments of the last few years have made it quite possible, if not probable, that these two conditions will shortly be reversed and that direct current will be used for power transmission and alternating current for power utilization; except for the difficulties of handling high voltages with direct current and the lack of suitable variable speed motors using alternating current, the present set-up probably would never have existed.

It is proposed, in a series of three articles, to give the various developments that have brought about a possibility of change in the present condition. The first article will cover the question of transmission.

Direct current transmission has the following advantages over alternating current.

First, the cables are capable of transmitting more current on account of the absence of skin effect.

Second, much higher voltages can be used because, in alternating systems, due to surges and reflected waves, it is possible to build up voltages very much greater than the normal voltage. The only voltage limitation with direct current is the electron tube which has to handle these voltages.

Third, and most important of all, it can be used for much greater distances than can alternating current; in fact, at present, no one can foresee any definite limitation due to distance whereas with alternating current there is a very positive limitation, at present on account of the capacity and reactance of long circuits; this distance is about 300 miles and there is no probability of increasing it greatly.

Fourth, it makes possible the tieing together of circuits of entirely different frequencies.

Fifth, it will be possible to use cables in trenches instead of conductors on high structures, reducing first cost and maintenance.

Sixth, it will be possible to use a ground return, thus reducing the cable costs by one-half.

Its only disadvantage is that more equipment will be necessary since an additional transformation at each end of the circuit will be required.

In connection with the fifth advantage, listed above, it is proposed to use insulated cable, instead of wires suspended from insulators on poles; by placing these cables in the ground, the difficulty of suspending them, which exists at present, will be removed; also protecting sheaths, to prevent mechanical injury, can be used with direct current but not with alternating current. All of the above should tend to reduce the very high initial cost, maintenance, and hazards of high tension wires which exist today as a part of the very elaborate and expensive system of towers and insulators which constitute a modern, high tension transmission system. Its vulnerability to high winds, rain, sleet, snow, and lightning are well known.

In addition to there being two systems of transmission according to whether the current is direct or alternating, there also are two systems according to whether the transmission is at constant potential or constant current. Most of the installations at present use constant potential but the constant current system has some advantages and, if direct current is to be used, the constant current method automatically gives the leading current which is necessary for inverter circuits; this detail will be discussed later when the various parts of the circuits are discussed. Constant current transmission, when using direct current, has the following advantages—

First, it is much safer since short circuits can do not great harm.

Second, switching is much simplified, since main circuits can be switched without drawing large arcs, as any circuit can be short-circuited before disconnecting it.

Third, the method used for obtaining constant current gives a suitable circuit for electron tubes working as inverters when supplying a load having a lagging power factor. This will be discussed later in this paper.

Its disadvantages are—

First, on open-circuit, it attempts to build up an infinite voltage to maintain the constant current, but this accident is easily guarded against by horn gaps; in fact, open-circuits occur much less frequently than short-circuits and are much more easily guarded against.

Second, it requires more equipment than does the constant potential circuit.

Third, at light loads, it is less efficient than the constant potential circuit.

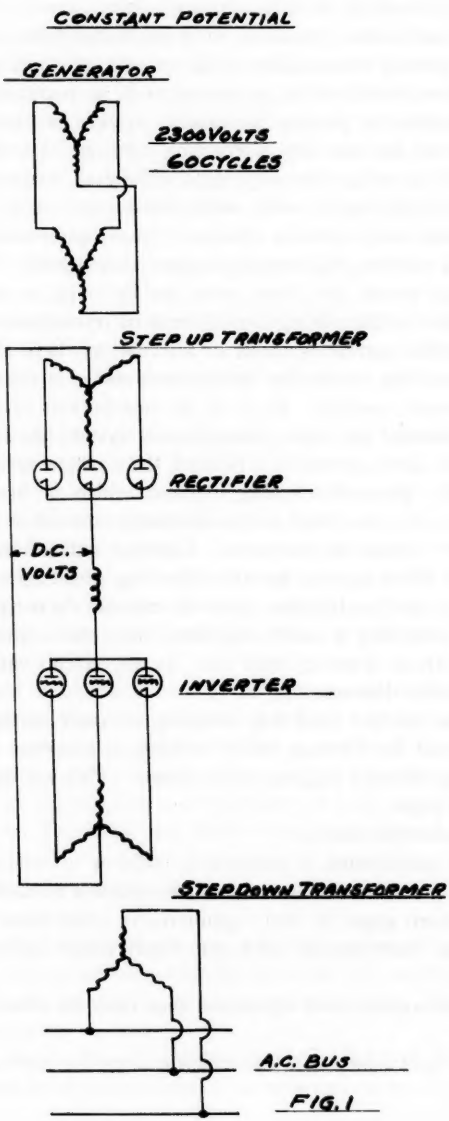

CONSTANT POTENTIAL
GENERATOR
2300 VOLTS
60 CYCLES
STEP UP TRANSFORMER
RECTIFIER
D.C.
VOLTS
INVERTER
STEP DOWN TRANSFORMER
A.C. BUS

FIG. 1

It should be added that constant-current circuits are still in the experimental stage. Constant potential circuits are so much more common and so much better understood at the present time, that that type of circuit will be used for our first discussion of direct current transmission systems. The simplest form of this system is shown diagrammatically in Figure 1, which gives the various parts of the circuit, starting with a generator and ending with an ordinary alternating current power bus.

The generator supplies current at standard frequency and voltage; this is stepped up to the desired transmission voltage by a transformer; it is then rectified into direct current by electron tubes; on arrival at its destination, it is inverted back into alternating current by controlled electron tubes; it is next stepped down by a transformer to the desired voltage; the frequency of this alternating current will be the same as that of the circuit which is being supplied since this frequency will be used to control the inverter tubes. In other words, it is entirely independent of the generator frequency so that a generator of any voltage and frequency can be used to feed any other circuit of wholly different frequency and voltage. As stated before, this is a constant potential circuit since all voltages, both direct and alternating, are constant. For reasons which will be discussed later, this type of circuit can only be used to supply a power bus which has a leading power factor. Since few power circuits are of this type, it will be necessary to supply equipment for converting the power bus to a leading power factor system before the constant potential system can be used.

Before proceeding with a discussion of this and other circuits, it will be best to analyze the component parts of the circuit, beginning with the tubes. The type of electron tube to be used for rectification or inversion is still being investigated. Thyratron or hot cathode type tubes have been mostly used to date, on account of their ability to withstand high voltages; however, the ignitron or mercury pool cathode type of tube is being tried for this purpose and has many advantages. Also there is the Marx valve which has great promise for very high voltages.

The Naval service is familiar with the thyratron tube which has been used for various control purposes on board ship. It consists

of an evacuated tube, either metal or glass, filled with mercury vapor and containing an anode, a control grid and a hot cathode. The grid controls the point at which the tube conducts or fires.

The ignitron tube is an evacuated tube having an anode and a mercury pool for a cathode; the point at which the tube conducts or fires is controlled by an igniter, which is an auxiliary anode dipping into the mercury; when the voltage on this is positive and sufficiently great, an arc will be struck and the tube will conduct.

The Marx valve is still in the laboratory stage. It consists of two main electrodes with two auxiliary electrodes between them, one auxiliary electrode being on each side of the axis of the main electrodes. The whole is enclosed in a vessel containing air at several atmospheres pressure. The high pressure is used because the breakdown voltage is higher under that condition than at atmospheric pressure. The valve operates by breaking down the gap from the main to the auxiliary electrode. The air is kept in circulation through the gap between electrodes.

The purpose of all these tubes is the same—that is to act as a non-return valve, permitting current to flow in only one direction and at a certain time. The control is lost as soon as the current starts to flow and the valve will then conduct for 120 electrical degrees; this value is, of course, only true for three-phase rectifiers or inverters and the width of conducting band will vary with the number of phases. Also there is a certain amount of time necessary for the transfer from one tube to another, but for the moment we can neglect this as it does not affect the theory of operation. In the case of rectifier tubes, ordinarily the control or firing point will not be changed as there will be no need to change the output voltage of these tubes; therefore, if hot cathode tubes are used, the control grid will be unnecessary as the shift, or commutation from one tube to the other will be performed automatically by the supply voltage; when the voltage curves cross, the transfer will take place. If an ignitron tube is used, the igniter will be necessary, since this tube can not pass current at all till the igniter strikes the arc; however, the igniter setting will be constant. With a Marx valve, the operation will be similar to an ignitron.

With the inverter, the conditions are somewhat different; the time of firing must be controlled in order to bring about commuta-

tion from one tube to another at the proper time; therefore a grid for control of hot cathode tubes will be required; for the ignitron, the igniter firing point can be controlled in the same way. There are other points of difference between rectification and inversion and a more detailed comparison will now be necessary to explain the points raised in the first part of the paper.

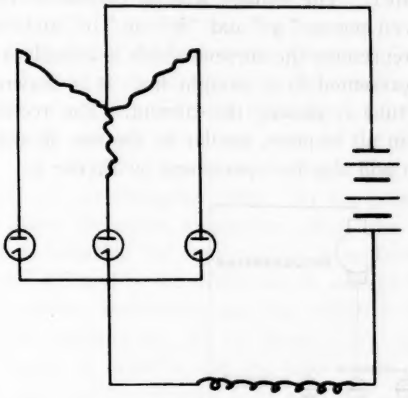


FIG. 2

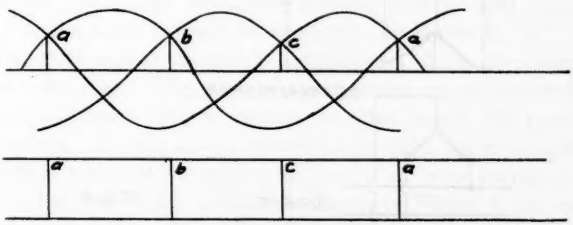


FIG. 3

Figure 2 shows a simple form of rectifier such as might be used for charging a storage battery; no control element is necessary. If it is desired to iron out the ripples in the current so as to produce a steady direct current, then a reactor must be placed in the circuit in series with the battery. We shall then have a condition such as is shown in Figure 3. Here the sine waves represent the electromotive forces imposed on the tubes by the generator. Assume that

one tube begins to conduct at the point marked " a "; it will continue to conduct till the point " b " is reached, when another phase will take up the conduction and continue it to point " c," where the third phase picks up, and so on; actually, the transfer from one anode to another will not be instantaneous as shown in the figure but, for the moment, we can neglect this irregularity which will be covered in a later paper. The voltage will be equivalent to the average voltage between points " a " and " b " or " b " and " c," etc. The lower curve represents the current which is actually a constant and should be represented by a straight line; it is drawn in blocks to show which tube is passing the current. The rectifier shown in Figure 1 is, in all respects, similar to the one shown in Figure 2 and its action will also be represented by Figure 3.

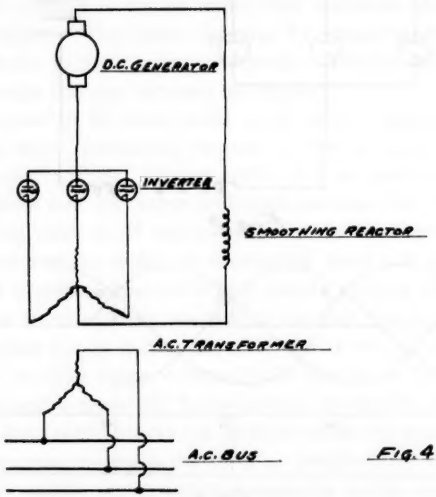


Fig. 4

In Figure 4, there is shown an inverter circuit. Here we have a direct-current generator supplying current to the inverter, consisting of three electron tubes having control elements; these tubes feed a transformer, which in turn supplies an alternating current power bus; it is necessary to interpose a transformer, or other device, to provide a neutral for completing the direct-current circuit, if only three tubes are used. Assume that the inverter is

supplying a bus which is supplied with an alternating e.m.f. from other sources; then this e.m.f. can be used to control the firing point of the inverter tubes, thus fixing the frequency. In order to understand the inverter action we shall refer to Figure 5. Here the full sine waves represent the electromotive forces of the system which is connected to the bus. To operate in parallel with this, the supplied electro-motive force (from the inverter) must be 180 degrees in phase from (opposite to) the bus e.m.f. The dotted sine waves represent the e.m.f.'s of the inverter. In fixing the point on these dotted curves at which the tube begins to conduct we have a condition entirely different from that of the rectifier; it will be necessary to advance the firing point of the tube by some angle, such as " α," in order to provide a commutating or reversing e.m.f., such as " e," for changing tubes. At the point where the current shifts from one phase to another phase, the voltage differential which is available for commutation is represented by the voltage marked " e," and is the difference in voltage between the phase which is already conducting and that which it is desired to have take up the conduction. If the firing point were not advanced, " e " would be negative and the tube would not conduct. Therefore, the tube will fire at some point such as " a," conduct for 120 degrees, and then the next tube will be fired at " b," and so on. To further clarify the difference between rectifier and inverter action Figures 3 and 5 should be compared. In Figure 3, " a," " b," etc., represent points at which commutation from one tube to another takes place. This point of commutation can be retarded by any desired amount by grid control; in other words, the point of commutation " a," etc., can be moved to the right but it can not be advanced as would be the case if the point " a " were moved to the left. In the case of the inverter as shown in Figure 5, the exact opposite is the case. The point of commutation can be advanced by moving " a " to the left but it can not be retarded. The reason for this is, that the commutating voltage is the counter e.m.f. supplied by the bus and which is 180 degrees in phase from the inverter voltage as shown in Figure 5. It can not be moved to the right (retarded) nor can the rectifier be moved to the left (advanced) because, in either case, the commutating voltage " e," or voltage differential, would become negative and the tube would not conduct.

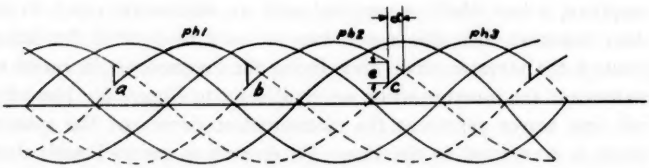


FIG. 5

This difference as to the firing point of the tubes of an inverter and rectifier causes another difference between rectifier and inverter action. In the case of a rectifier, if the point of commutation is at the intersection of the curves of e.m.f., the power factor will be unity; if the point of commutation is retarded (moved to the right), then the current (or power factor) will be lagging. The exact reverse is true with an inverter; the point of commutation is always advanced (moved to the left) and the current (or power factor) will always be leading. The power factor can never be unity (as in the case of a rectifier) for the reason given above—that is, the commutating e.m.f. is supplied by the counter e.m.f. of the bus. This explains the point brought up in the first part of the paper where it was stated that an inverter can only be used to supply a circuit where the power factor is leading.

The difference between rectifier and inverter action has an effect on the rating of the tube itself. In order to explain this effect, we shall have to refer to Figure 6. The upper sine wave shows inverter action, the middle curve controlled rectifier action, and the lower curve plain rectifier action. For simplicity, only a single phase inverter and rectifier is shown. It should be borne in mind that these curves represent the voltage imposed across the tube from anode to cathode, and not the phase voltage of the output circuit, as shown in Figures 3 and 5. The time during which the tube has negative voltage imposed on it is indicated by the arrows. It will be seen that the time of negative voltage for the inverter is relatively very short. Consequently there is very little time for deionization of the tube to take place before positive voltage is imposed on it and this results in making it necessary to rate some tubes at considerably lower voltage or current when using them for inverter purposes than when using them as controlled rectifiers. The deionization of the tube is necessary in order to make it possible to hold

back the positive voltage which will be imposed on it, as shown in Figure 6. In the case of the inverter, as stated above and as shown in Figure 6, the time elapsing before the imposition of the positive voltage is extremely short.

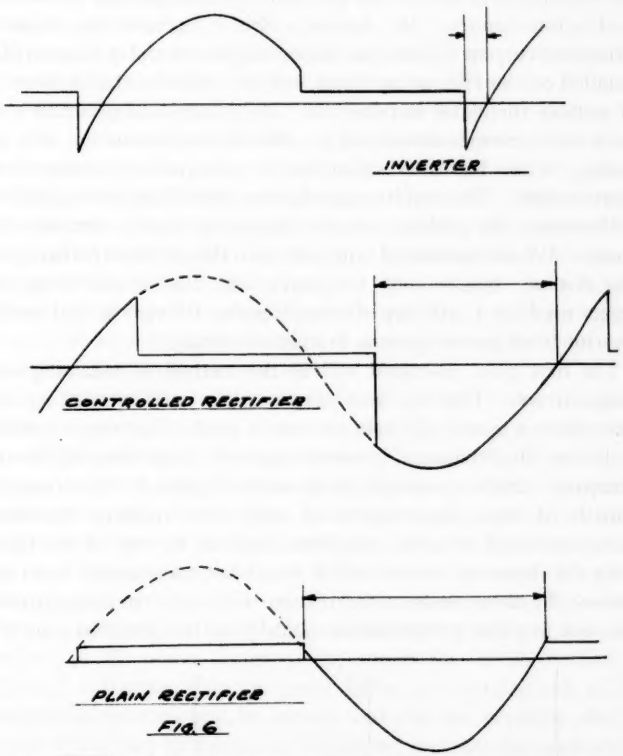


FIG. 6

We have now covered the various parts of the circuit shown in Figure 1 and can proceed to a discussion of constant current circuits. The use of constant-current for transmission is not a new idea but it has never been used to any great extent. The possibilities of its use were not great till the advent of the electron tube, which has changed the whole picture. Thury developed a constant-current system which is in use in Europe today but only to a very

limited extent. In this system, direct current is generated in the usual manner and the voltage is stepped up by placing several generators in series; at the receiving end, motors are in series; the current is maintained at a constant value by automatically shifting the brushes; it is not a very attractive system and has never been used in this country. Mr. Austin, a British engineer, has proposed a constant-current system for use on shipboard and it was actually installed on the *Viceroy of India,* but it is believed that it is not at all suitable for Naval installations. The motors and generators are much more complicated, much less flexible and about the only advantage is the increased safety due to removal of damage from short-circuits. The result attained is not worth the price paid.

However, the problem we are discussing here is entirely different. We are concerned with only two things, the first being the long-distance transmission of power, and the second being the urgent need for a safe way of tieing together the various and sundry assortment of power systems in existence today.

The first point discussed will be the method of obtaining constant current. This is a very simple matter with alternating current, where a monocyclic network can be used. The idea is credited to the late Dr. Steinmetz, formerly engineer of the General Electric Company. Such a network is shown in Figure 7. As shown, it consists of three capacitors tuned with three reactors, the whole being connected in series; the three leads at the top of the figure carry the incoming current which is at constant potential from any source; the three leads at the bottom will carry constant current; this fact was first proved mathematically by Dr. Steinmetz; as it is

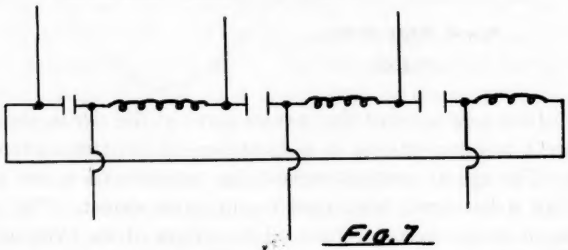


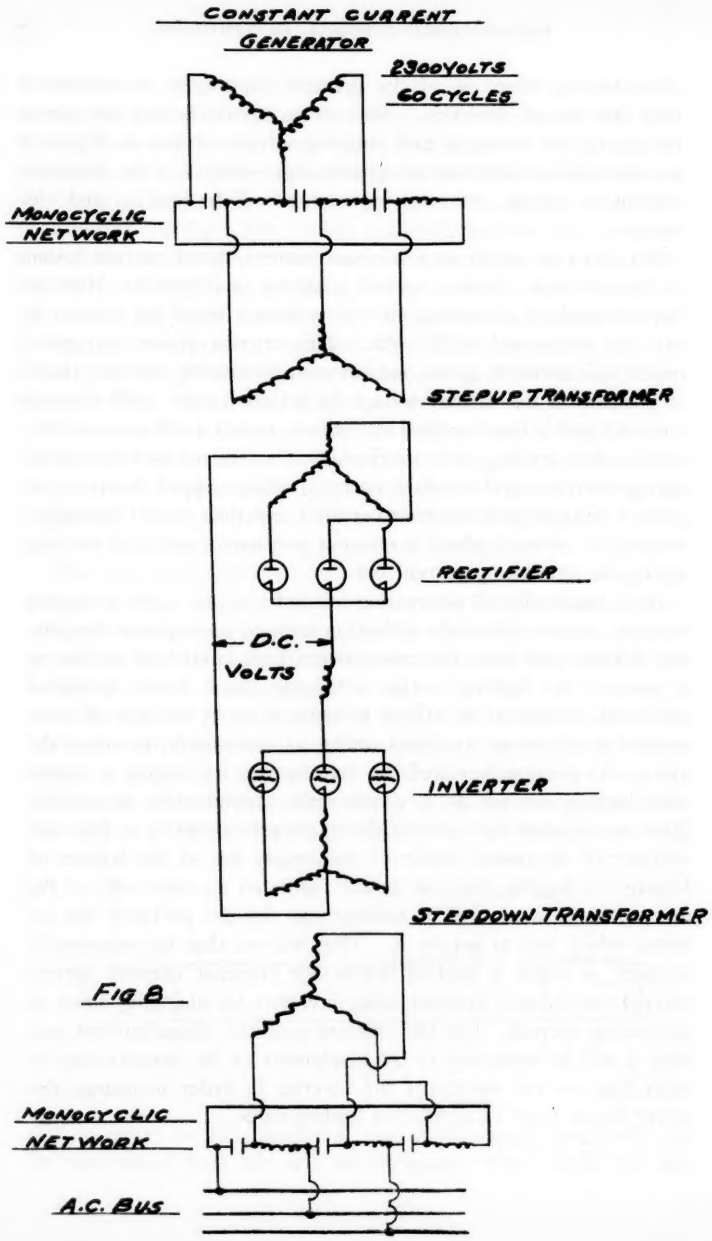
Fig. 7

not necessary to this discussion, the mathematical proof will not be reproduced here but will be accepted. This circuit has one

characteristic which is of the greatest importance in connection with the use of inverters. This characteristic is that the power factors of the incoming and outgoing circuits shown in Figure 7 are identical in value but of opposite sign—that is, if the incoming current is lagging, the outgoing current will be leading, and vice versa.

We can now construct a constant current, direct current system of transmission. Such a system is shown in Figure 8. Here we have a standard alternating current generator supplying current at, say, 60 cycles and 2300 volts. This current passes through a monocyclic network, giving out constant alternating current; this is stepped up to the desired voltage by a transformer (still constant current) and is then rectified into direct current (still constant current); after arriving at its destination it is inverted back into alternating current (still constant current), then stepped down to the desired voltage (still constant current) and then passed through a monocyclic network where it emerges as constant potential for supplying the alternating current bus.

Now practically all alternating current systems carry a lagging current; motors, especially induction motors, most power consuming devices, and even the transmission lines contribute to the reactance of the system so that a lagging power factor is almost universal in spite of all efforts to bring it up by the use of overexcited synchronous machines acting as condensers, or other devices. As previously stated, an inverter can not supply a system with lagging current as it would make commutation impossible. Here we now see the value of the monocyclic network in this connection; if the power factor of the supply bus at the bottom of Figure 8 is lagging, then the power factor on the other side of the monocyclic network will be leading and this fits perfectly the inverter which has to supply it. Thus we see that the monocyclic network is really a perfect device for constant current, direct-current transmission systems, using inverters for changing direct to alternating current. For the constant potential, direct-current systems it will be necessary to use condensers of the synchronous or other type on the outlets of the inverter in order to change the power factor from a lagging to a leading value.


CONSTANT CURRENT
GENERATOR
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MONOCYCLIC
NETWORK
STEP UP TRANSFORMER
RECTIFIER
D.C.
VOLTS
INVERTER
STEP DOWN TRANSFORMER
MONOCYCLIC
NETWORK
A.C. BUS

Fig 8

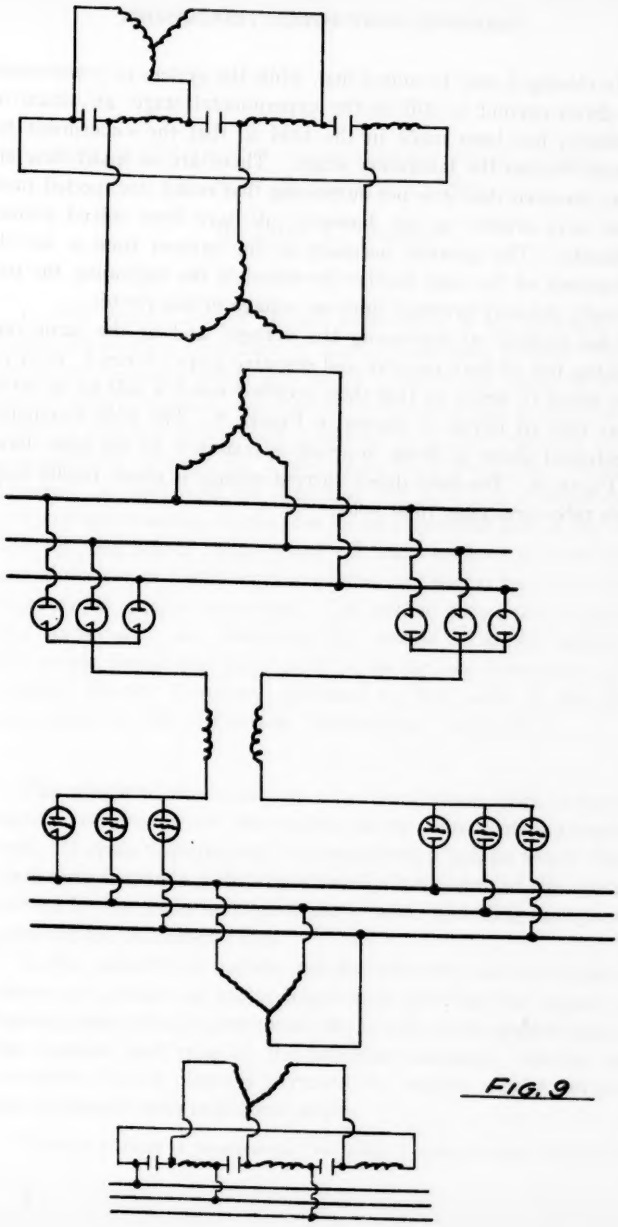

FIG. 9

In closing it may be added that, while the system of transmission by direct-current is still in the experimental stage, an actual installation has been made in the field so that the experiment has passed beyond the laboratory stage. There are so many new circuits involved that it is not surprising that many unexpected problems have arisen; so far, however, all have been solved without difficulty. The greatest necessity at the present time is for development of the tube itself. As stated in the beginning the tube is really the only practical limit on voltage in this circuit.

One method of increasing the voltage, and at the same time making use of both positive and negative loops of e.m.f., is to put two tubes in series so that their rectified e.m.f.'s will be in series. This type of circuit is shown in Figure 9. The field installation mentioned above as being in actual operation is of the type shown in Figure 9. The total direct current voltage is about 15,000 volts, each tube rectifying 7500 volts.

ESTIMATION OF CONDENSER PRESSURES OF NAVAL CONDENSERS.

By John R. Weske.*

In this article, Doctor Weske contributes a mathematical and highly provocative discussion of marine condenser design. He has developed formulæ which will be of interest and value to a condenser design engineer, and it is to be regretted that in his development he did not apply these formulæ to a determination of the pressure loss through the steam space in a particular condenser. However, he does treat the condenser not merely as a water recovering or water saving device, but as an important link in the engineering plant whose capacity and efficiency becomes a direct measure of the power finally made available, and that is becoming recognized as the proper viewpoint. The author gained his experience and background, and developed the method of attack outlined in this article during two years spent in the turbine department of the General Electric Company, followed by five years in the design department of the Bethlehem Shipbuilding Corporation.

The weight of the condenser of a naval steam plant is approximately one-quarter of the weight of the entire main propulsion unit. If space requirements are considered it will be found that the condenser demands a disproportionally large part of the space reserved for the main unit, particularly when including the space for drawing the condenser tubes.

In the majority of installations the size and location of the condenser is a factor of major importance affecting the engine room layout, since often it determines the length of the engine room and the location and rake of the propeller shafting. As the steam pressure of naval plants is increased, the relative weight and size of the condenser tend to become larger.

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These facts serve to emphasize the importance of achieving greater compactness in the design of surface condensers. Fundamentally this is possible through increase of the rate of condensation, resulting in a smaller condensing surface, or through decrease of the size and spacing of tubes. Either practice leads to an increase of the pressure at condenser inlet, the former primarily as a result of the increased temperature drop, the latter because of the pressure drop on steam side due to higher steam velocities.

Whereas this pressure drop is a negligible factor in small and lightly loaded condensers, it assumes considerable values in high-capacity condensers of large size and has become particularly noticeable in condensing plants with effective air ejector equipment. The question of the expected pressure drop on the steam side may no longer be disregarded in the design of high-capacity condensers.

It is possible to derive certain relations between the design of the condenser and the physics of heat transfer and of steam flow on one hand, and the pressure drop on the other. These relations have been correlated and adapted to a method of estimating condenser pressures presented in this paper. This method, while accepting the available data on condensation without regard to the special problems presented by them, has been found useful in the design of several high-capacity condensers and yields results which compare favorably with the performance of condensers in operation.

ONE-DIMENSIONAL TREATMENT.

Conditions in a condenser vary in general with the depth and with the width of the condenser as well as with the extent of the tubes. Variations across the width and along the tubes, however, are secondary compared with the variation in the principal direction of flow. An exact and comprehensive three-dimensional or even a two-dimensional treatment is not justified in view of the absence of precise knowledge of the condensing process. Certain approximations made for the purpose of a one-dimensional analysis appear to be warranted, particularly since the secondary variations referred to may be accounted for by superposition or by corrective factors.

The following simplifying assumptions and approximations are made in calculating condenser pressures:

1. It is assumed that all the steam entering the condenser is condensed on the condensing surface proper, no condensation taking place in the air cooler. Also, the effect upon condensation of the presence of air in the steam is disregarded.

2. The velocities and steam conditions are assumed constant along any tube.

3. The mean steam path is defined as the line in a tube sheet layout extending from the inlet of the condenser to the air cooler inlet, dividing the total quantity of steam flow at any point in half.

4. Neglecting secondary effects, lines of constant pressure are assumed to extend across the tube sheet section. The direction of steam flow is everywhere normal to these lines of constant pressure, its velocity being constant and equal to the mean velocity across the line. The lines of constant pressure intersect at right angles with the mean steam path.

EQUATIONS FOR THE PRESSURE DROP.

The relations pertaining to the condensing process can be formulated by certain equations. The decrease of steam flow $dQ\left[\frac{lb}{hr}\right]$ between two constant pressure lines a distance dx apart (where x distance measured from inlet along the mean steam path) is equal to the amount of steam condensed on the condensing surface dS lying between these two lines. With q = local rate of condensation this equation of steam quantities is in differential form:

$$dQ = qdS \qquad (1)$$

The local rate of condensation can be stated in terms of the factors entering into heat transfer

$$q = \frac{MTD}{rR} \qquad (2)$$

wherein the mean temperature difference MTD between the steam temperature t_s (constant along a tube) and the water temperatures t_1 and t_2 at inlet and outlet, respectively, is

$$MTD = \frac{t_2 - t_1}{\log_e \frac{t_s - t_1}{t_s - t_2}} \qquad (3)$$

further r = heat rejected per pound of steam condensed in $\frac{BTU}{lb}$.

This includes the latent heat of the steam and a portion of the heat of the condensate in case of undercooling. The variations of r throughout the condenser are small. For purposes of estimation of pressures r = q25 $\frac{BTU}{lb}$ may be chosen, which is an average value for 10 per cent moisture in the steam.

R = total resistance to heat flow in $\frac{ft^2 hr\ degF.}{BTU}$ which is the reciprocal of the heat transfer coefficient h.

The velocities of steam flow through the condenser depend on the area between the tubes. If A be the total area along any line of constant pressure at x based on the minimum distance between tubes, then the corresponding mean weight velocity is

$$G = \frac{Q}{A} \tag{4}$$

and, with v = specific volume of the steam at x, the linear velocity

$$V = \frac{Qv}{A} \tag{5}$$

The pressure drop resulting from steam flow through the tube bundle can be expressed by the Fanning equation. The slope of the pressure curve is

$$\frac{dp}{dn} = 4f \frac{V^2}{2vg} \tag{6}$$

wherein p = pressure in $\frac{lb}{ft^2}$

n = number of tube rows along the mean steam path
f = Fanning coefficient
g = acceleration of

When integrating eq. (1) between air cooler inlet (x_2) and any point x, substituting Q in (5) and then V from (5) in (6) the pressure slope is

$$\frac{dp}{dn} = \frac{2 f v}{g A^2} \left(\int_{x_2}^{x} q \, d S \right)^2 \qquad (7)$$

Since the functional relations of the quantities appearing in equation (7) are involved, formal integration is not possible. It may, however, be replaced by summation over sections of the condenser for which the various quantities may be assumed constant. A condenser section is defined as a part of the condenser tube bundle bounded by two lines of constant pressure and extending across the entire width of the condenser. Indicating mean values of a section by the subscript i, the pressure drop in any section is

$$(p_1 - p_2)_i = 2 f_i n_i \frac{V_i}{g} G_i^2 \qquad (8)$$

wherein n_i = number of tube rows of the section $G_i = \frac{Q_i}{A_i}$, Q_i being the quantity of steam flow entering the succeeding section plus half the quantity of steam condensed in the section considered.

thus, $$G_i = \frac{1}{A_i} \left(\frac{q_i S_i}{2 r R_i} + Q_i, (i + 1) \right) \qquad (9)$$

The specific volume of the steam can be expressed in terms of the mean pressure of the section $\left(\frac{p_1 + p_2}{2} \right)_i$

$$V_i = \frac{2 K_i}{(p_1 + p_2)_i} \qquad (10)$$

K denotes the product of pressure and volume, pv, which varies less than 10 per cent in the entire range of condenser pressures. It may therefore be assumed to be constant with sufficient approximation. The values of K_i are readily obtained from the steam tables. When substituting equation (10) in (8), transposing and

summating over the number of sections z the following expression for the pressure at condenser inlet is obtained

$$p_1 = \sqrt{p_2^2 + \sum_{z}^{I} \frac{4\, f_i\, n_i\, K_i}{g}\, G_i^2} \qquad (11)$$

By means of this equation it is possible to calculate the effect upon the condenser inlet pressure of variations of the pressure at air cooler inlet, of the quantity and temperature of circulating water, and of such other factors resulting from design, steam flow or heat transfer as influence the pressure drop in any part of the condenser.

The pressures at top of condenser are plotted against pressures at air cooler inlet in Figure 1 for a particular case in order to give an idea of the relation expressed through equation 11.

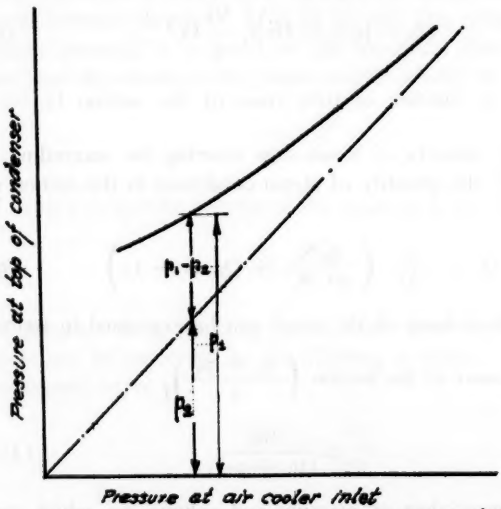

Fig. 1 Effect of variation of pressure at air cooler inlet upon pressure at top of condenser.

The pressure at air cooler inlet is purposely used instead of the air ejector suction pressure, since tracing the influence of changes of the latter would require a special investigation of air cooler performance.

SOLUTION OF THE EQUATIONS.

Estimation of condenser pressures should go hand in hand with the preliminary design of a condenser. For purposes of calculating the pressures of a condenser layout for a specified load condition the tube sheet layout is divided into a number of sections, preferably from 3 to 5. These sections extend over the entire steam flow area and are bounded by two lines of equal pressure.

Certain design data should then be tabulated for the entire condenser (exclusive of the air cooler) and individually for each section. These data include the number of tubes, the area of condensing surface, the free area of steam flow and circulating water flow, the number of tube rows along the mean steam path, also the average number of rows for each section over which the condensate cascades.

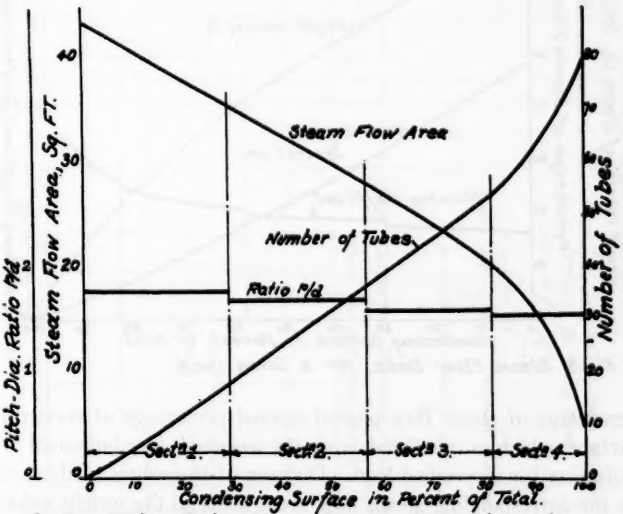

Fig. 2. Design Data for a given condenser layout.

The area of steam flow, the number of tube rows, and the mean ratio of pitch normal to the flow to diameter $\frac{p}{d}$ should be plotted as a continuous curve against the percentage of condensing surface (in per cent of total), as shown in Figure 2.

It is seen from equations (8) and (9) that the pressure drop in a given section is a function of the amount of steam condensed in the succeeding sections. In general, this would require successive calculation of all sections, beginning with the last. However, since this is cumbersome and susceptive to inaccuracies a trial-and-error method has been chosen instead. This method requires a tentative assumption of the probable distribution of condensation and yields accurate results after one or two approximations. Graphical presentation of the different steps of the calculation has been found useful, as it affords greater clarity. In Figure 3 there is shown the

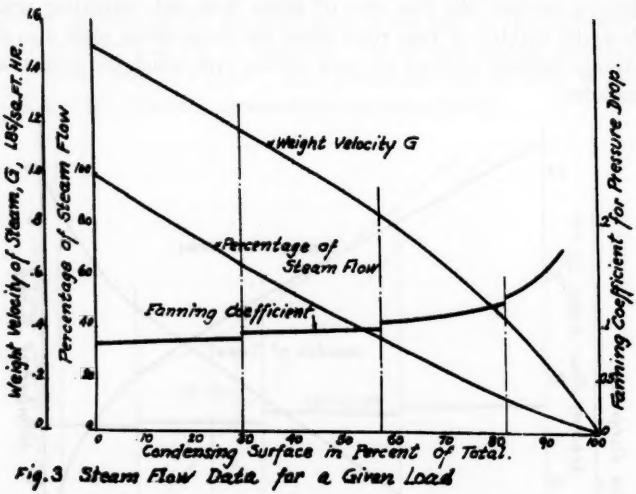
Weight Velocity of Steam, G, Lbs/sq.ft. Hr.
Percentage of Steam Flow
Weight Velocity G
Percentage of Steam Flow
Fanning Coefficient
Fanning Coefficient for Pressure Drop.
Condensing Surface in Percent of Total.

Fig. 3 Steam Flow Data for a Given Load

percentage of steam flow plotted against percentage of condensing surface, which is calculated from the assumed distribution of condensation for a specified load. Division of the values of this curve by the corresponding steam flow areas leads to the weight velocity curve shown in the same graph. The graph shows, further, the values of the Fanning coefficients [1] obtained from Chilton and Genereaux's curves,[2] Figure 4, for the proper value Reynolds

[1] For some of the following data on heat transfer and pressure drop the author is indebted to Mr. Morris Weitzner, of the Bethlehem Shipbuilding Corp., Quincy, Mass.

[2] Th. H. Chilton and R. P. Genereaux "Pressure Drop across Tube Banks," Am. Inst. Chem. Engrs., Vol. XXIX, 1933.

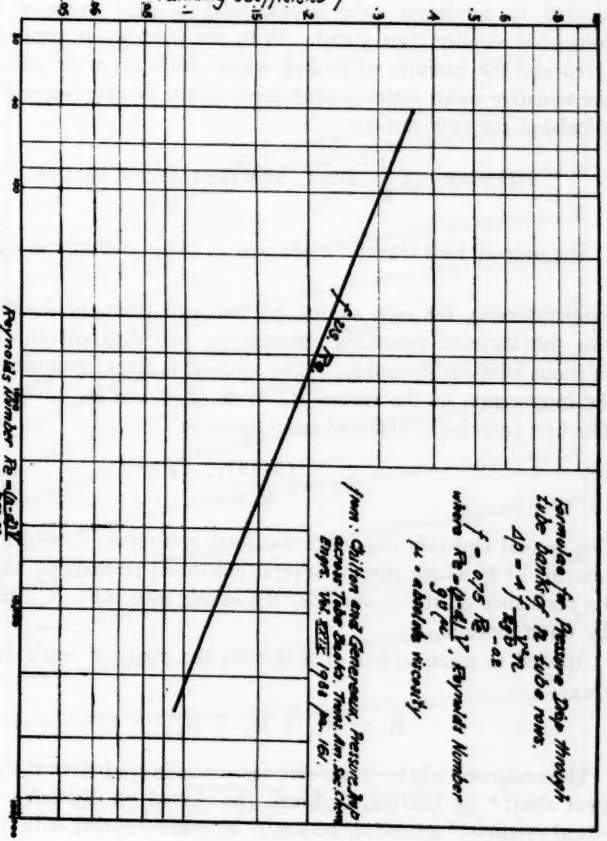
Fanning Coefficient f
Reynolds Number Re = DVρ/μ
Formulae for Pressure Drop through tube banks of 12 tube rows.
Δp = 4 f (G²/2ρ) 12
f = 0.75 Re^-0.25
where Re = DVρ/μ, Reynolds Number
μ = absolute viscosity
from: Colburn and Genereaux, Pressure Drop across Tube Banks, Trans. Am. Soc. Chem. Engrs. Vol. XXIII 1929 p. 161.

Fig. 4. Fanning Coefficient for pressure drop through staggered tube banks vs. Reynolds Number.

number. These coefficients, although originally for staggered arrangement only, were used for diamond and radial pattern alike, since the effect of the pattern is diminished for tube banks of great depth. It has been found that these Fanning coefficients, when applied to condenser tube banks, tend to give pressure drops somewhat smaller than actual. With the inlet water temperature given and the quantity of cooling water either given or estimated, the tentative mean outlet temperatures of the cooling water can be calculated for each section.

SOLUTION FOR $\frac{1}{R_i}$ AND t_{si} FOR TENTATIVE q VALUES.

The over-all heat transfer coefficient $h_i = \frac{1}{R_i}$ and the mean steam temperature t_{si} for each section are obtained from the solution of two simultaneous equations representing two different functional relations between R_i and t_{si}. The solution is found graphically by the intersection of the curves $R_i = \varphi_1 (t_{si})$ and $R_i = \varphi_2 (t_{si})$. The first equation is obtained from equation

$$R_i = \frac{(MTD)_i}{\varphi_i r} \qquad (12)$$

The second equation expresses the total resistance R, which is a function of t_s, as the sum of several individual resistances, namely, the resistance on the steam side, R_s, in the tube wall, R_m, and on the water side, R_w.

Applied to mean values of a section, the equation reads as follows:

$$R_i = R_{si} + R_m + R_{wi} \qquad (13)$$

The reciprocal of the steam-side resistance is read from the alignment chart [3] by Chilton, Colburn, etc., based on Nusselt's theoretical relations,[4] amended, however, by multiplication with a constant coefficient 1.5 as suggested by Parr.[5] The resistance in the tube wall is proportional to the thickness of the wall and inversely

[3] Refer to foot note 1.

[4] Reprinted in McAdams, "Heat Transmission," p. 262.

[5] "The Engineer," 1921, p. 113.

proportional to the thermal conductivity, its value referred to the outside diameter is $0.00068 \frac{\text{ft}^2\text{hr deg F.}}{\text{BTU}}$ for standard $\frac{5}{8}$" #18 BWG tubes of Admiralty bronze. The water-side resistance R_w is estimated from experimental data by Eagle and Ferguson,[6] from

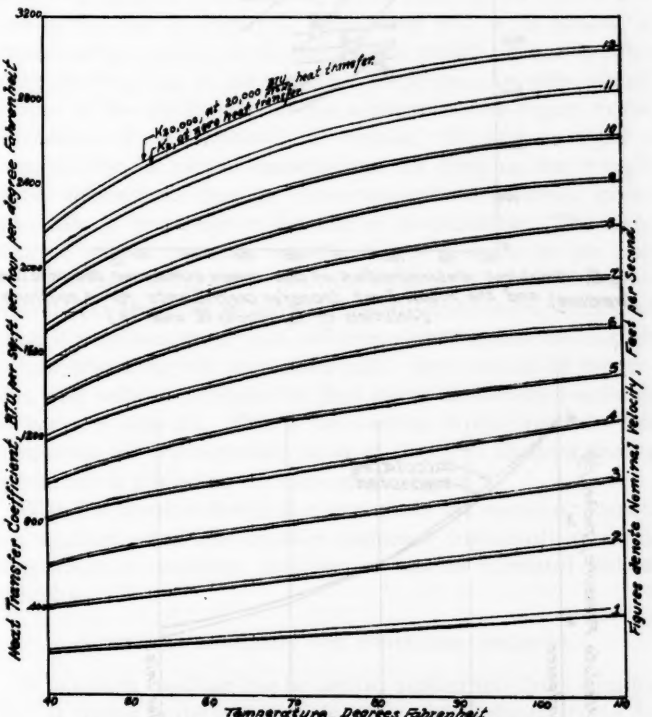

Fig. 5. Water-side Heat Transfer Coefficients $K = 1/R_w$ for 5/8"-#18 B.W.G. Tubes, based on I.D.

which the curve sheet, Figure 5, has been calculated. Increase of heat transfer at inlet is taken into account by adding 25 I.D. to the length of the tubes. All values should be referred to O.D.

[6] "Engineering," November 28, 1930, et seq.

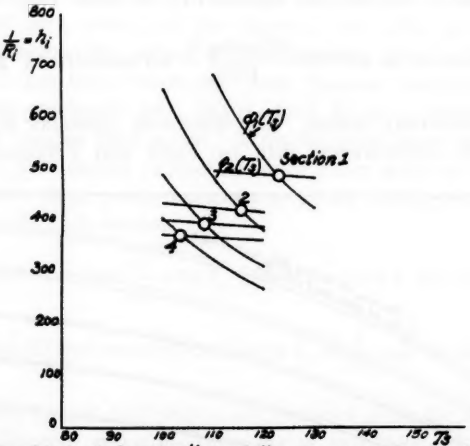

Fig. 6. Graphical determination of the mean condenser temperature (pressure) and the mean heat transfer coefficients for 4 sections. (Solution of equations 12 and 13.)

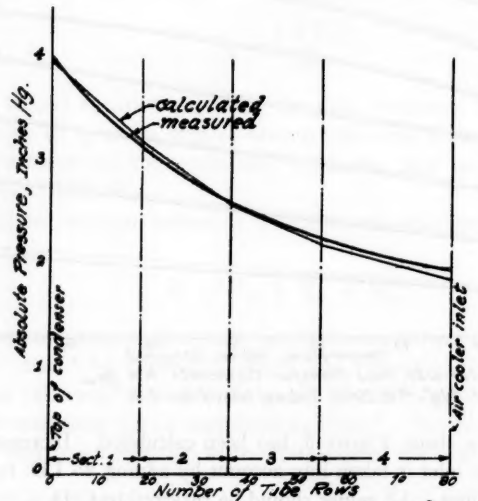

Fig. 7. Calculated and measured condenser pressures for max. load.

The graphical solution for R_1 and t_{s1} is shown in Figure 6 for a condenser divided into four sections. With t_{s1} known, the corresponding mean steam pressure can be obtained from the steam tables for each section and plotted against the number of tube rows along the mean steam path n as abscissa, see Figure 7. The pressure gradient for the midpoint of each section is readily obtained by solving equation 7, substituting mean values of the section and plotting the slope in Figure 7. The result will be, in general, a discontinuous pressure curve, consisting of straight lines with steps at the dividing lines of the sections. These steps are only natural because of the arbitrariness of the assumption with regard to the distribution of condensation.[7] It remains, therefore, to apply a correction for the rate of condensation. In doing so, use is made of the circumstance that the mean temperature difference varies practically in proportion to the rate of condensation. The error incurred in this correction is only one per cent for 10 per cent change of condensing rate. Both the mean pressure and the mean pressure gradient must be subjected to this modification. The final result is a continuous curve of pressures plotted against the number of tube rows along the mean steam path. By rounding off the corners with suitable parabolas the final curve of absolute condenser pressures is obtained. This is the solution of the problem. For comparison the corresponding curve of pressures obtained from a special test is plotted on the same graph, Figure 7.

With the pressure distribution throughout the condenser known, the apparent mean heat transfer coefficient customarily used for comparison of condenser performance may be calculated without difficulty.

MINIMUM CONDITION FOR CONDENSER PRESSURE.

A minimum condition can be derived qualitatively from equation 11. It results in the postulate that the weight velocity should decrease approximately inversely proportional to $1/\sqrt{fx\,K}$, which increases along the mean steam path. The final weight velocity curve, Figure 3, thus is a criterion for the design of the condenser from the standpoint of pressure drop.

[7] M. Wulfinghoff, "Power," October 18, 1931.

PROXIMATE CALCULATION.

In cases in which great accuracy of the result is not essential, a proximate method may be used for calculating condenser pressures. This method is similar to the calculation just described, except that it dispenses with the division of the condenser into sections. Instead of mean values for the sections, the mean values for the entire condenser are obtained and the pressure at the inlet is arrived at by way of the mean condenser pressure and the mean pressure gradient. This proximate method commends itself particularly for the estimation of condenser pressures at partial loads.

THE RELATION OF ENGINEERING TO NATIONAL DEFENSE.

By Rear Admiral H. G. Bowen, U. S. N., Member.*

On the night of January 20, 1937, at a banquet given under the auspices of the American Engineering Council at the Hotel Mayflower, Washington, D. C., Admiral Bowen delivered this speech to a gathering made up of representatives of the Washington chapters of the various engineering societies, and many distinguished guests from all parts of the country. His aim in the speech was to bring home to his audience—many of them with no Naval affiliations whatever—the tremendous diversification of Naval engineering, the wide range of design responsibility which rests on the various material Bureaus of the Navy Department, and some realization of the intricacy of the engineering laboratories that are created today in the warships that ply over, under, and on the sea. The speech was received with so much attention and interest, that it is here presented, in the hope that it will reach many engineers, interested but not informed on the extent and many ramifications of the Naval engineering establishment.

Mr. Toastmaster, Fellow Engineers, and Guests:

I feel greatly honored to have the opportunity to speak to you tonight upon the relation of engineering to national defense and I would like to call your attention to the fact that one hundred years ago on the 23rd of this month the contract was signed for the main engines of the U.S.S. *Fulton,* the first steam powered vessel in our Navy.

In the first place a modern navy, such as ours, is just about as highly a mechanized organization as one is likely to find anywhere. And it is absolutely dependent on the engineer for its existence and its continuance.

* Engineer-in-Chief, U. S. Navy, and Chief of the Bureau of Engineering, Navy Department, Washington, D. C.

What does the Navy consist of? *First, ships:* Battleships, light and heavy cruisers, gunboats, submarines and destroyers and their respective tenders, aircraft carriers, patrol plane and seaplane tenders, mine layers, mine sweepers, oilers, fleet tugs, repair ships, store ships, ammunition ships, cargo ships, hospital ships and floating dry docks. *Second, aircraft:* In the *heavier than air single purpose group,* bombing, observation, fighting, torpedo, scouting, patrol, utility, training, transport, and experimental airplanes; in the *heavier than air double purpose group,* bomber fighters, scout bombers, patrol bombers, patrol torpedo, torpedo bombers and scout observation airplanes. In the *lighter than air group,* rigid airship, non-rigid airship and balloon. *Third, the shore establishment:* The Navy Department is probably the largest shipbuilding concern in the world. We have underway or authorized ninety-five (95) naval vessels. Half of these are being built at navy yards. The other half are being built at private shipyards in accordance with preliminary plans formulated by the Navy Department. The Navy also operates a gun factory, powder factories, a proving ground, a research laboratory, an electrical laboratory, an engineering experiment station, a model tank and a boiler laboratory. *Fourth, the naval communication system:* In order to communicate with vessels all over the world under all conditions of interference, whether natural or man made, the Navy Department maintains probably the most intricate communication system in existence. Every ship, every shore station, and every plane is part of this system. It utilizes wave lengths from about 20,000 meters to a few centimeters. Parts of this system operate at speeds as fast as 500 words per minute.

The Navy in building ships utilizes many types of engineering machinery, accessories and specialties, which are drawn from practically the entire industrial engineering field. Such equipment as is available may be improved upon or suitably adapted for the difficult operating conditions found in the naval service. These conditions include the effects of shock, vibration, corrosion of salt atmosphere, extreme temperature variations as well as weaving, rolling, and yawing of the ship's structure. An attempt to provide equipment adequate for such special service conditions is made through the use of various naval specifications based upon experi-

mental tests and operation in service and enforced by a comprehensive inspection service.

The power plant of a naval vessel consists of boilers, turbines, Diesel engines, electrical equipment and numerous auxiliaries such as refrigerating machinery and distilling apparatus. Boilers are either of the header type or the A type express, with superheaters controlled by a divided furnace arrangement, or by separately fired superheaters. To obtain additional efficiency economizers and air heaters are fitted in some installations. Turbines embody the electric turbo generator type or geared turbines with impulse and reaction blading combinations. Diesel engines for main or auxiliary power are of three general types, the single acting two-cycle, the single acting four-cycle and the double acting two-cycle, with various mechanical constructions existing under each type. Electrical machinery is now in a transition stage from direct to alternating current for many applications, with higher voltages predominating. There are numerous electrical control systems for interior communication, fire control, and radio. Refrigeration is accomplished by the vapor compression system utilizing carbon dioxide and freon as refrigerant gases. Distilling plants are of the low pressure type, in multiple effect and generally fitted in duplicate.

Fuel oil is the source of heat and power in both boilers and Diesels. In the control of this equipment many varieties of thermometers, pyrometers, combustion and smoke indicators, burners and meters are required. The conservation of heat is obtained by the careful selection of suitable fire brick, heat insulating materials, such as magnesia, asbestos, mineral wool, and metallic foil, each being selected for its proper use.

Many mechanical devices are employed, such as pressure control valves, speed controls and temperature controls. Indicators are employed which provide knowledge of operating conditions. Due to the extreme fluctuations of speed and power required in operating naval vessels, devices of special construction and design are required.

The necessity for dependability requires that all devices be rugged as well as sensitive. Since sea water and salt air are continually present the selection of proper materials and proper protective measures for all mechanical devices is a vital problem.

Due to the flexibility of the ships and the confined spaces allotted to engineering equipment, suitable provision for expansion of steam and other pipe lines must be provided. What a task this is I can emphasize by saying that it takes one hundred and twenty pages to record the necessary computations in connection with the pipe lines of a destroyer. For the same reason more care must be employed in the selection and installation of sleeve, ball and roller bearings.

The power problems of generation, distribution and current consuming devices define in a broad way the electrical system aboard ship. Thus starting with the ship's service Diesel or turbine driven generators, in conjunction with motor generator sets or transformers for conversion of power to make it adaptable to specialized uses, the power is transmitted through cables of the high voltage class, to the current consuming devices throughout the ship. Forming a part of this distribution system are devices of a protective nature, which include fuses, automatic circuit breakers, and relays of reverse current, overload and low voltage types. Automatic protection is supplemented by the automatic performance of such functions as those accomplished by voltage regulators and bus transfer.

Electrical insulation which is a primary and fundamental material in all electrical devices in industry, is especially important aboard ship, where it is subject to operating conditions which will result in easy breakdown and failure unless the highest quality material the industry can produce is procured. To this end an extensive program of testing and specification preparation is necessary, which has resulted in the procurement of satisfactory insulating materials of numerous types, including laminated and molded phenolic parts. Insulating material, such as fiber, mica, plastic sealing compound, insulating varnish and lacquer and tape of all types, have been investigated in order to obtain suitable materials for the naval service.

Knowledge of operation of the entire electrical system on board ship is provided by indicating instruments generally similar to those in use in power plants ashore. Audible signals or alarms of the electrical type are employed, not only to assist in the operation of machinery, but also to direct the ship's crew in their duties. Circuit breaking devices of all types, both automatic and non-

automatic, and fully enclosed, are used to control and protect the electrical system.

Going back to the *Fulton* for a moment, she was of 1200 tons displacement and had engines of 625 horsepower. It is interesting to compare previous times with our own and see how much more horsepower per man can be produced now than then. In those days one man produced forty-six (46) horsepower. In the days of the Spanish American War and a little later, 400 horsepower per man seems to be a representative figure for torpedo boats and destroyers. In our latest destroyers we have increased it to 1600 horsepower per man. In the battleship class output has been nearly doubled since the *Oregon*. In the cruiser class output has been increased seven times since 1900.

You will see from the above that the naval part of national defense is closely related to national industry and to the art of engineering. Sometimes engineering ashore receives a stimulus from engineering afloat and sometimes the stimulus flows in the opposite direction.

The Navy had long wrestled with the problem of gasoline fires in its 1600 motor boats. Due to the inherent nature of gasoline no satisfactory solution was obtainable at any cost. So the Navy went to the engineering talent of the country and was able to obtain Diesel engines in sizes of 25-horsepower, 65-horsepower and 100-horsepower, which have apparently met all our requirements and eliminated the fire hazard. These engines are light weight, high speed, rugged, reliable, and sure starters in cold weather.

As all of you know, the history of the submarine since the days before the great war has revolved around the slow but sure development of the Diesel engine. When we began building submarines at the beginning of the present building program, there was nothing on the horizon any different from what we had always had except the new Diesel engines being produced for the transportation industry. As a matter of fact, I think the Navy has had just as much to do in the production of this new type as the transportation agency has. The adoption of this type and size of engine has been eminently successful and meets naval requirements to an extent not hitherto deemed possible.

The Navy is now engaged in and partly financing the development of light weight Diesel engines of an intermediate size and

which have an immediate possibility of adaptation to some of the vessels of the auxiliary shipbuilding program. This development will mark the introduction of a new type of American built Diesel and it is proceeding by private contract.

In 1933 in the depths of the depression, the administration decided to build up the Navy to treaty strength for several reasons, one of them as a means to relieve unemployment. This program had not only a beneficent effect on the shipbuilding and associated industries, but also gave engineers an opportunity to develop new types. It is rather hard at present to realize to what depths industrial production had sunk in certain lines. At one time the only turbine work in the turbine shop of a great manufacturer was turbines for the Navy, and at about the same time, the shipbuilding industry was accepting naval work, sometimes at cost or less, in order to keep their plants and their engineering staffs together. Of course, the keeping of engineering staffs together was one of the problems that confronted industry during the worst phase of the depression. All of us understand that these staffs are collected laboriously over the years and represent a large part of the asset which has come to be known as "a going concern."

At the beginning of the building program, I think I am entirely correct in stating that marine engineering in the merchant marine had progressed further than it had in our Navy. One of the first steps in our new design was to assimilate the advances in engineering proven in the merchant marine. From that point we have rapidly progressed and I am confident that new designs for the merchant marine will increasingly embody developments which have been made in naval engineering as a result of the initiation of the building program.

The Navy has pioneered in the introduction of alternating current aboard ship, not only for propulsion purposes, but for auxiliary use, and it is this recent application which I am now emphasizing. So far as I know there are no ships in any foreign navies which use alternating current for auxiliary purposes and no ships in any merchant marine except in the case of the seatrain vessels, which operate from New York to Havana. The reasons for changing from direct current to alternating current for this purpose are many and obvious to all you engineers, but it was the high state of development of the alternating current art in the United States

which enabled us to make this change completely, expeditiously, and successfully.

The Navy offers a great field for light weight, high speed, high capacity machinery. Such machinery is always bound to be far in advance of commercial requirements and commercial demands. This is caused by the fact that it is the ideal of every warship designer to pack as much speed, as many guns and as much armor as is possible, in a constricted space and with a positive limitation on weight. Weight has been at a premium ever since the first limitation of armaments conference was signed. If the limitation treaties didn't accomplish anything else they made warship building much more expensive, put a premium on weight, and gave a tremendous stimulus to the engineering world to meet these new and exacting conditions.

Naval boilers occupy much less space, weigh far less, and are operated at much higher capacity than any other boilers ashore or afloat. The increasing requirements in these respects by the Bureau of Engineering has stimulated the art of boiler design in this country and has resulted in a much better knowledge of circulation and combustion than would have obtained otherwise.

In the turbine field similar exacting requirements have led to a re-study of turbine blade design and to the determination of much more exact and scientific formulas for the design of blading.

In the storage battery field, a field which is so important to the submarine, continual development has been eagerly applied by the Navy as fast as industry has been able to offer it.

The present self-contained air-cooled motors and generators of widespread power plant use were born in the mind of a naval designer who was looking for a motor which would operate in the oil charged atmosphere of a submarine's bilges and not suffer from continual insulation trouble.

A word or two about design and how it is handled in the Navy. The various bureaus of the Navy Department do some of their design work and some is obtained from private contractors. In the case of the Bureau of Engineering, for which I can speak authoritatively, the field embraced is so huge that it is utterly impracticable for the Bureau of Engineering to do all of its own design. There are so many different branches of engineering involved in the main propulsion, the auxiliaries, and control of auxiliaries, guns, turrets,

and searchlights, that it would be utterly impossible for the Bureau of Engineering to do all of its own design unless that Bureau alone were to take possession of the Navy building and employ draftsmen and engineers in sufficient numbers to completely fill it.

Congress in its wisdom has required that all purchases except in a few special cases be the result of competition. I am all for this, because we not only get competition in price, but we get competition in design features. We have all of the engineering brains of a continent to draw from in our competition and this results, over the years, in the selection of the best possible designs that can be developed. No one activity, be it bureau or otherwise, could possibly compete with such an enormous field of talent. As it is, the Bureau of Engineering is constantly at the saturation point in checking design which emanates from contractors and in preparing specifications and preliminary plans for new construction and in doing such pure design work as it is absolutely necessary for it to do.

The Navy is in continuous touch with practically all of the research laboratories of the country in order to take advantage of latest developments, for it is incumbent upon us to be the first to put to the service of national defense the work of our engineers. We are prepared to go just as far and just as fast in naval engineering as the shoregoing engineers are prepared to accompany us. Naval warfare can be viewed as a struggle between the applied science of the respective combatants.

I think you will agree with me that the naval part of our national defense is almost exclusively a product of engineering, and that our Navy is just about as highly a mechanized institution as it is possible to accomplish.

There is one thought I would like to leave with you tonight and that is—a navy cannot rise to any greater heights than the engineering profession of the country to which it belongs. I would not have you think that I have forgotten completely the human element necessary in all undertakings. I have taken for granted the fact that we have a personnel in our Navy and a morale second to none, and without which nothing would be possible. But that personnel must be equipped with machinery superior to any other machinery afloat. In battle the first salvo that lands pays big dividends and it is perfection in equipment which makes that possible, and the credit goes to the engineer.

A ROLL OF HONOR OF NAVAL ENGINEERING INVENTIVE GENIUS.

On November 23, 1936, in the city of Washington, was held the Centennial Celebration of the American Patent System, climaxed by a most unique banquet, widely attended, and more widely discussed. As a feature of the affair, an announcement was made of the names of twelve men, who, it was deemed by the sponsors, had, during the history of this country, reflected the most credit on it by their inventive creations. The list was as follows:

Robert Fulton	*1765-1815.*
Eli Whitney	*1765-1825.*
Samuel Finley Breese Morse	*1791-1872.*
Charles Goodyear	*1800-1860.*
Cyrus Hall McCormick	*1809-1884.*
Elias Howe	*1819-1867.*
George Westinghouse	*1846-1914.*
Alexander Graham Bell	*1847-1922.*
Thomas Alva Edison	*1847-1931.*
Ottmar Mergenthaler	*1854-1899.*
Charles Martin Hall	*1863-1914.*
Wilbur Wright	*1867-1912.*

As almost any good, wide-awake school child can tie at least ten out of the twelve names to an invention, the list appears to be a very good one, and worth while to remember. It was made up from lists submitted to the Centennial officials from many different sources, and from all parts of the country. One such list was submitted by the President of the American Society of Naval Engineers, restricted to inventors and creators, closely allied to the Naval service, if not actually of it. While the list has an official certification, it seems to have some curious and even obvious omissions, probably because it was rather hastily prepared, and the Editor suggests that a useful purpose might be served, if each member of the

Society sufficiently interested, would write in to the Secretary-Treasurer, reporting any names he feels should appear in the Roll, with life dates, and a brief biographical reason for the appearance of any name suggested. The names of Rear Admirals Taylor, Fiske, Sims, and Griffin, and Mr. Emmett of the General Electric Company occur offhand to the Editor. If the response to this suggestion is encouraging enough, the Roll will be re-published in some subsequent issue of the JOURNAL *in an amplified form, and the Editor will feel that the Society has contributed definitely toward the perpetuation of a noteworthy record of historical accomplishment.*

NAVAL OFFICERS.

John Batiste Bernadou, Commander, U. S. Navy:

Naval Academy Class 1880. Died 2 October, 1908. Developed smokeless powder.

Washington I. Chambers, Captain, U. S. Navy:

Naval Academy Class 1876. Died 23 September, 1934. Catapult-Amphibian—Model Basin.

John Adolphus Dahlgren, Rear Admiral, U. S. Navy:

Born in Philadelphia, November 19, 1809; died at the Navy Yard, Washington, July 12, 1870. Appointed midshipman, February 1, 1826; rear admiral, February 7, 1863; twice Chief of Bureau of Ordnance; invented the famous Dahlgren gun (first gun which was shaped to correspond with decrease of pressure from breech to muzzle), and introduced howitzers ashore and afloat. Destroyer No. 187 and Torpedo Boat No. 9 were named *Dahlgren.*

William Hale Driggs, Commander, U. S. Navy:

Naval Academy Class 1869. Died 6 January, 1908. Invented rapid fire gun.

Charles Wilson Dyson, Rear Admiral, U. S. Navy:

Naval Academy Class 1883. Died 25 October, 1930. Invented small tube express type water tube boiler. Also made many improvements in the design of screw propellers.

George Wallace Melville, Rear Admiral, U. S. Navy:

January 10, 1841—March 17, 1912. Born in New York. Entered the Engineer Corps of the Navy in 1861. Chief of Bureau of Engineering 1887-1903 (16 years). One hundred and twenty (120) ships were built during this period. He introduced innovations in these, including water tube boilers, vertical reciprocating engines, triple screws, and reduction gears.

Henry C. Mustin, Captain, U. S. Navy:

Born February 6, 1874, Pa., Naval Academy Class 1896; died August 23, 1923. Developments in applying telescope sights for gunnery use. Target sights. Aviation ordnance.

John Rodgers, Rear Admiral, U. S. Navy:

Born 8 August, 1812; died 5 May, 1882. Marine Railways.

Frank Julien Sprague, Ensign, U. S. Navy:

Naval Academy Class 1877. Resigned 15 April, 1884. Died 25 October, 1934. Developed electrical motors and experimented with measurements of electrical resistance. Was member of Naval Consulting Board.

Charles Francis Stokes, Surgeon General, U. S. Navy:

Died in 1931. Surgeon General of the Navy from 1910 to 1914. He was the inventor of the well known Stokes stretcher familiar to nearly all officers and men of the Navy. What is probably not so well known is that his ingeniously designed stretcher permits the transportation of sick and injured on board ship with safety and speed not previously possible. A seriously ill or injured man can be removed from the most inaccessible places, through narrow passageways, up steep ladders, raised in a vertical position, with safety even when serious fractures exist, and it permits the patient to be lowered over the side of a ship by boat cranes or davits with a maximum of security and comfort. Modifications of this design have been adopted and are used by navies and civilian maritime agencies throughout the world. The invention greatly facilitates the movement of wounded after naval action and is undoubtedly an important contribution to the effectiveness of the Navy.

Albert Reynolds Couden, Rear Admiral, U. S. Navy:

Naval Academy Class 1867. Died 7 April, 1923. Developed steel for armor plate.

Robert Gracy Denig, Commander, U. S. Navy:

Naval Academy Class 1872. Died 9 April, 1924. Developed reciprocating engines.

Benjamin Franklin Isherwood, Rear Admiral, U. S. Navy:

October 6, 1822—June 19, 1915. Born in New York City. Appointed to Engineer Corps, U. S. N., 1844. Designed first feathering paddle wheels for U. S. S. *Water Witch* in 1852. Designed class of gun boats for Russian Navy in 1859. Made first investigations of boiler and engine energy losses under actual operating conditions in steam vessels, 1859 to 1871. Demonstrated limiting effective expansion ratios for reciprocating engines, 1860. Appointed Engineer-in-Chief, U. S. N., 1861. Appointed the first Chief of the Bureau of Steam Engineering in 1862, and served in this capacity until 1870. During the Civil War, he supervised the engineering installations of more than 600 steam-driven naval vessels. He was much criticized at this time because the weight of the machinery installations was greatly in excess of concurrent shore practices. He rebutted these accusations by stating that he made the machinery in these ships extra heavy as a precaution against inexperienced handling by war personnel. He made extensive experiments with the screw propeller at the Navy Yard, Mare Island, in 1869-1870.

Albert Abraham Michelson, Lieutenant Commander, U. S. N. R.:

December 19, 1852—May 9, 1931. Born in Poland. Came to the United States in 1854. Graduated from the Naval Academy in 1873. Served required two years after graduation, then commenced his career as teacher and physicist in the capacity of Professor at the U. S. Naval Academy. Thereafter he studied and taught abroad and in the United States. Although he never received an academic degree, he received eleven (11) honorary degrees. His work on physics, particularly the velocity of light, laid the foundation for modern physical theory. 1918—Appointed Lieutenant Commander, U. S. Naval Reserves, and served during the great war.

Dashiell, Robert B., Assistant Naval Constructor, U. S. Navy:

Naval Academy Class 1881—Died 8 March, 1899. Breech mechanism.

Esterly, Marcus H., Lieutenant, U. S. N. R.:

Killed in explosion of *ZR-2,* 24 August, 1921. Application of direction finder to dirigibles.

Walter Martin McFarland, Lieutenant, U. S. Navy:

Naval Academy Class 1879. Resigned 5 July, 1899. Died 4 March, 1935. Pioneered modern installation of boilers and engines.

Herbert C. Rodd, Lieutenant Commander, U. S. Navy:

Killed in plane crash at Hampton Roads, 15 June, 1932. Application of radio to airplanes.

OTHER THAN NAVAL OFFICERS.

Alexander Graham Bell:

Telephone.

David Bushnell, Captain, U. S. A.:

American inventor, was born in Saybrook, Conn., in 1742; died in Warrenton, Ga., 1824. Called the "Father of the Submarine"; graduated from Yale in 1775; made a study of submarine warfare; constructed a diving boat, called it the *American Turtle*; made a number of unsuccessful attempts to blow up the enemy's ships of war, one the *Eagle,* in New York Harbor, in 1776; another the *Cerebus,* anchored off New London, in 1777. Submarine Tender No. 2 was named *Bushnell.*

Thomas Alva Edison:

Electric light and power. Member of Naval Consulting Board.

John Ericsson:

Inventor, born July 31, 1803, Wermland, Sweden; came to the United States in 1839; died March 8, 1890, New York, N. Y. Developed and put in use the screw propeller, the caloric engine, the solar engine. Collaborated with Captain Stockton to build first steam frigate, U. S. S. *Princeton,* 1844. Also designed guns for this ship. Designed vessel of ironclad type in 1854. This ship was never built, but had the essential features of the *Monitor,* which he built in 1862. Inventor of armored turret and turrets which trained. He was the most prolific inventor of his time in regard to naval and marine mechanisms. Destroyer No. 56 and Torpedo Boat No. 2 were named *Ericsson.*

John Fitch:

Inventor, was born in East (now South) Windsor, Conn., January 21, 1743; died in Bardstown, Ky., in June, 1798. In April, 1785, conceived the idea of steam as a motive power and completed his first model of a steamboat that year. Continued his experiments, and built a second boat, which made its trial trip on the Delaware at Philadelphia, August 22, 1787, in the presence and to the great satisfaction of the Convention assembled to frame the Federal Constitution. A still larger boat in October, 1788, and still another in April, 1790, continued to demonstrate with their increased speed and facility the value of his invention.

Robert, Fulton:

American inventor, was born in Little Britain, Lancaster County, Pa., 1765; died in New York City, February 24, 1815. At the age of 13 he constructed paddle wheels which he applied successfully to propel a fishing boat. An avowed advocate of freedom of the seas, owing to British interference with commerce during European wars. This led to his interest in the development of naval material. 1797—Developed naval mine and torpedo. 1800—Built "diving boat" *Nautilus,* the forerunner of present day submarines. One of his diving boat models was tried in France and a board appointed by the Emperor Napoleon I to decide upon its merit. The invention was not approved either in France or England. Fulton returned to America and in 1807 proved that steam could be applied to boats for propulsion. His first steamboat, the *Clermont,* launched in the spring of 1807, made her first trip to Albany from New York (150 miles in 33 hours) in August of the same year. Fulton built the first war steamer, for New York Harbor defense, *Fulton The First or Demologos.* Armament—30 32-pounders firing red hot shot. Gunboat No. 49 was named *Fulton.* During his latter years he experimented with underwater guns for firing torpedoes.

Elmer Ambrose Sperry:

Engineer, inventor, was born in Cortland, Cortland County, N. Y., October 12, 1860; died June 16, 1930. In 1880, founded the Sperry Electric Company, to manufacture dynamos and arc lamps and also other electric appliances; in 1900 became interested in electrochemistry and established a research laboratory in Washington,

D. C. He made many developments and inventions of use to the Navy in ordnance, fire control, and engineering. Most notable among the latter were the gyro-compass, first installed in U. S. S. *Delaware*, 1910; the aeroplane stabilizer, first used in 1913-1914 (other gyro-control plane instruments followed); then high intensity searchlight, first used in 1918. In addition to the above, he personally developed and was granted more than four hundred (400) patents. 1915—He was made a member of the U. S. Naval Consulting Board. During the latter part of his life he was engaged in the development of a compound Diesel engine, of which he had, at the time of his death, made eight (8) models. Application of gyroscope to fire control.

James Watt:
Steam engine.

Wilbur Wright:
Born in Millville, Ind., April 16, 1867; died in Dayton, Ohio, May 30, 1912. In 1903, with his brother Orville, invented a successful motor-driven aeroplane. In 1896 his machine made the first experimental extended heavier-than-air flights. He, it appears, was the first to design and build a machine capable of carrying a man, and the Wright brothers were the first to design, build, and fly a machine which carried a man. He made numerous flights in the United States and abroad. He was awarded a medal by French Academy of Sciences, 1909, also many others. He was a member of the Aero Club of America. Heavier-than-air Aircraft Tender No. 1 was named *Wright*.

George F. Asbury:
Breech Mechanism.

Glen H. Curtis:
Developed the first seaplane.

Reginald Fessenden:
Underwater signaling and radio continuous wave.

Charles Goodyear:
Vulcanizing of Rubber.

H. A. Harvey:
Armor Plate.

E. M. Haslett, Waldo W. Willard:

Joint inventors of Selsyn system of fire control. (Note—It is not known whether Mr. Haslett is dead.)

John Philip Holland:

Inventor, was born at Liscannor, County Clare, Ireland, in 1842; died August 12, 1914. Laid his first plans for a submarine before the United States Navy Department in 1875; received the first contract from the United States for a submarine torpedo boat in 1895, but this vessel, the original *Plunger,* was never finished. New contract made in 1900, covering the purchase of two submarines built at the Crescent Shipyard, Elizabethport, N. J., and operated with success prior to acceptance. These vessels, known as the *Holl* and *Plunger,* were the first of the type on the Navy List. Submarine Tender No. 3 was named *Holland.*

J. S. Howell, Captain, U. S. A.:

Inventor of first self-propelled torpedo.

Samuel P. Langley:

Pioneer airplane development.

Charles S. Larrabee:

Cryptography.

Hudson Maxim:

His work with explosives. Was member of Naval Consulting Board.

Samuel F. B. Morse:

Telegraph and Morse Code.

Lawrence Sperry:

Gyro Stabilizer for Aircraft, Dirigible Hook-On, Amphibian, Fly-wheel Catapult.

Hervey D. Williams:

Inventor of BB submerged torpedo tube and Waterbury Tool Company variable speed gear—also blast meter for measuring blast of guns—pressure meter for measuring pressure inside of guns. Variable pitched propeller for torpedoes.

Dr. Louis W. Austin:

Pioneer radio expert in Navy Department. Famous for wave propagation studies.

Emile Berliner:
Microphone.

O. Chanute:
Glider.

A. H. Emery:
Radial Expansion Methods of building large guns.

Richard Jordan Gatling:
Inventor of the "Gatling Gun."

Chadwick Hall:
Aircraft Structures.

Simon Lake:
Developer (1894) of the submarine type bearing his name.

Charles M. Manley:
Langley's five-cylinder, air-cooled, radial engine.

Sylvanus Reed:
Aircraft propellers.

Elmer Stone:
Aircraft Powder Catapult. Arresting Devices.

Samuel Wesley Stratton:
July 18, 1861—October 18, 1931. Born in Illinois. Created the Bureau of Standards under the sponsorship of President Theodore Roosevelt. As Lieutenant Commander in charge of Chicago Naval Militia, he entered the service during the Spanish-American War, 1898, with the rank of Lieutenant. He was assigned with his unit to the *Texas*. He started organizing the Bureau of Standards in 1901. During his life he constantly collaborated with the Navy in the development of all types of naval material.

Nathan B. Stubblefield:
Credited with having been the first to broadcast the human voice by radio. He made his first public demonstration in 1902, after 10 years of experiments.

WHAT IS EXPLOSION PROOF ELECTRICAL EQUIPMENT?

By E. F. SEAMAN, MEMBER.*

Mr. Seaman discusses in this article, some recent findings of the Bureau of Mines of the Department of the Interior, as these apply to certain special classes of marine electrical equipment and apparatus. On naval and merchant ships which carry gasoline and fuel oil there is always an attendant danger due to the unavoidable, or unexpected concentration of explosive fumes when volatiles are given off in restricted spaces. Certain types of electrical apparatus, such as small portable blowers, fans, pumps, and lights, must frequently be carried into such spaces, or even used in them continuously, and Mr. Seaman points out the limitations which must be applied in their present-day design. As such devices are now covered by the "Safety at Sea" requirements, all marine designers should be familiar with the limitations of electrical apparatus when covered by the designation "Explosion Proof."

I DEFINITION AND SCOPE.

Inasmuch as it is impractical at all times to prevent air and gas from accumulating to form an explosive mixture, it becomes necessary in reducing the explosion hazard in confined spaces to eliminate so far as practicable, the cause of ignition of the gaseous mixture—a possible flame or spark. If a unit of machinery can be introduced and be safely operated in the presence of explosive gases, it follows that an explosion proof design has been produced. This is the ideal, and must obtain in any design to which the term "explosion proof" can be applied.

The present discussion will be confined largely to items of portable electrical equipment since machines falling within this classi-

* Associate Electrical Engineer, Bureau of Engineering, Navy Department, Washington, D. C.

fication require special precautions to be taken in their construction, in addition to the normal safety features which should be present in all types of electrical machinery which are intended for use near explosive gases.

II PRACTICAL DESIGN VERSUS DEFINITION.

Since electrical circuits, and especially those in rotating machines are inherently spark-producing, it is evident that true explosion-proofing must be sought in other ways than by dependence on the complete elimination of sparking. This is an ideal conception but impractical of attainment in present-day design. It can be reduced, however; operating enclosures can be tightened to confine the sparks; and special precautions can be taken in the introduction and attachment of cable; and it is along such lines that practical development has taken place.

Accidental sparks may be either of electrical or mechanical origin. The mechanical type of sparking, caused by the impact of two metals, can be eliminated in a proper design by the use of a non-sparking material such as aluminum, in the construction of exterior parts exposed to impact. It is usually not necessary to include in the non-sparking classification such parts as bolts, nuts, and washers.

Electrical sparking cannot be eliminated, but its probability can be reduced to a satisfactory degree by the use of the best quality of cable, proper insulation and attachment; careful design of brush-rigging, commutators and slip rings; and the provision of grounding leads to serve as protectors in case of fault. It may be argued that in marine installations where the operating unit always rests on, or is in direct contact with a metal deck and the ship's structure, that such a contact is an adequate ground connection. This is not the case, however, since particles of foreign matter insulating in character, or a film of grease, will cause momentary interruptions in the electrical circuit between frame and structure, when shock occurs such as that due to gun-fire. These interruptions of circuit will be attended by sparks if a ground exists. A further justification of a ground connection integral with the portable power cable lies in the fact that the special form of connecting plug requires a special receptacle to take it, thus permitting a definite control over points at which connection to the power circuit can be made safely.

The Navy Department has found it desirable to spend much time, expense, and effort to produce a portable cable with the best resistance to abrasion and wear, and consequent long life, and such a type of cable should always be used with explosion-proof electrical apparatus. A rigid inspection of the cable when purchased to insure full compliance with specification requirements is essential to determine its safety in service.

The cable, when installed in an explosion-proof unit, is protected to prevent extremely sharp bends which would cause mechanical injury. One method of protection is the use of a rounded bell mouth where the cable enters the unit casing. This mouth is constructed of insulating material of high dielectric strength and insulation resistance, so that a spark to ground will be prevented in the event of a cable fault. A good molded phenolic material has proven useful in this application.

III DISTINCTIVE TYPES OF ENCLOSURE.

In the selection of an enclosure to house an electrical unit designed to operate in the presence of explosive gases, two lines of thought have governed the design. In the first, every effort is made to eliminate the possibility of gases entering the housing where they might be set off by sparking of the moving parts, and this results in an "airtight" enclosure. In the second, it is assumed that the possibility of admission of the dangerous gases to the interior is beyond control, and design effort is directed to confining the explosion, if it occurs, to the interior of the enclosure. It may be defined as the "pressure relief" type of design.

It is important before either type of construction is adopted, that the safety characteristics of each be fully understood, and that their limitations be not overestimated; and in examining the designs it is essential that not only the initial, but also the explosion-proof integrity after a period of operation, be clearly determined.

IV AIRTIGHT DESIGN.

As has been set forth, it is the purpose of an airtight design to obtain a hermetically sealed unit; and it is undoubtedly true that such a design can be produced. But it is extremely doubtful whether the airtight characteristics originally present can be per-

petuated over a long period of service, and this will be evident from a review of the operating and maintenance conditions.

In such a design it is necessary to use gaskets for all joints. For certain of the parts, under the handholes for example, the gasket is required to perform its function properly after frequent disassembly and assembly. In such case, the natural aging of a resilient gasket material is accelerated through wear and tear in adjustment, and its contact with deleterious substances. The time when a gasket ceases to be effective cannot be readily determined, and even in its first removal it may be damaged sufficiently to render it useless as a seal against the entrance of dangerous gases. For these reasons, it is almost impossible to compensate for deterioration by periodic replacement. When it is considered that in addition to the foregoing difficulties, there is a definite "breathing" action through the relatively porous gasket material whenever the enclosure is subjected to a temperature change, the difficulty of maintaining airtightness in the enclosure will be apparent.

It will also be apparent that the airtight feature may in itself become a dangerous hazard. While the joints may not be sealed sufficiently tight to prevent a gradual admission of the explosive vapors, it is quite possible for them to be tight enough to prevent an instantaneous pressure relief in the event of an explosion in the interior. If the pressures so generated are of sufficient magnitude, the enclosure will rupture and the explosion will be transmitted to the surrounding atmosphere in its most dangerous form.

To guard against the possibility of such an excessive internal pressure, the idea of a safety valve in the form of a flame arrestor, or a slow pressure relieving device, at once suggests itself. But such a device can always be rendered inoperative by the entrance of foreign material or the products of corrosion, and proper pressure relief can be secured much more readily by designing to secure it throughout the enclosure.

V PRESSURE RELIEF DESIGN.

The discussion thus far has indicated that an airtight enclosure may enhance rather than diminish the danger of an explosion after a certain period of operation, and the length of this is indeterminate. The justification for using a design of the deliberately

pressure-relieved type is, that in it the faults found in an airtight construction are almost entirely corrected.

Primarily, a pressure relief design is based on the principle that gases shall have free access to the interior of the enclosure, through metal to metal joints having a maximum specified separation, so that in the event of ignition of the gas in the enclosure interior the ensuing explosion will not be disastrous for two reasons. First of all, the internal pressure will not reach an excessive value because of its ready dissipation through the joint interstices, and secondly, the flame accompanying the explosion will be cooled and extinguished in attempting to pass through the metal to metal joints which are made sufficiently wide to effect this result.

VI DESIGN DETAILS—PRESSURE RELIEF ENCLOSURES.

The United States Bureau of Mines has, as the result of exhaustive testing, set up standards of recommended limits and tolerances in pressure relief enclosure designs,* and these standards have been adopted and incorporated in Navy Department specifications which govern the purchase of explosion-proof types of electrical apparatus. In all cases the standards represent working limits which afford a reasonable balance between a minimum of explosion hazard, and a unit which it is practical to build and install.

A few of the more important standards which are followed in specifying pressure relief enclosures are as follows:

(*a*) Enclosures having an unoccupied air space of 60 cubic inches or more, shall have a joint width from inside to outside of not less than one inch when measured by the shortest path.

(*b*) No gaskets shall be used, and all joints shall be metal to metal. The separation of the joints, (*a*) above, shall be not greater than 0.004 inches. It is desirable to have these joints or flanges secured at least every 6 inches.

(*c*) If, in measuring the distance from the inside to the outside of a joint, it is found that a bolt hole forms a part of the path, the effective path through the joint will be considered to be the total distance less the diameter of the bolt hole.

* Schedule 2C. Explosion-Proof Mine Equipment—Department of the Interior, Bureau of Mines.

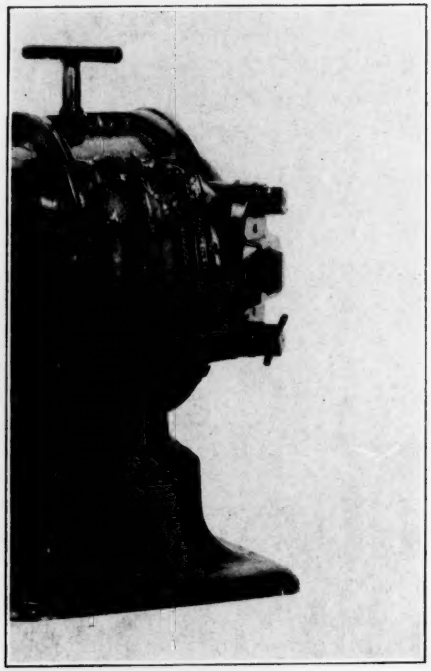

FIG. 1.

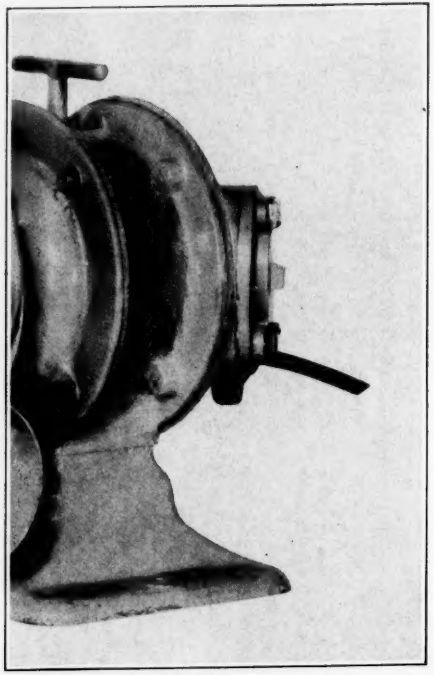

FIG. 2.

(*d*) Where handhole covers are secured by means of bolts, these bolts shall be such that they must be tightened with a wrench. Wing nuts are not permitted since they may be knocked loose by impact with a solid object.

(*e*) When a sealing compound is used where a cable passes through the casing, the compound shall have a sufficiently high flow point to insure that it will not flow out of place. The Navy Department is covering such a compound by a special specification.

(*f*) The flame path along a shaft from the interior to the exterior of the enclosure shall be not less than one inch, and the radial clearance shall not exceed 0.015 inch.

In Figure 1 will be seen a typical airtight type of housing, while in Figure 2 is shown a housing somewhat similar but of the pressure relief type. The extra width of the joints in Figure 2 should be especially noted, and also the absence of gaskets. In Figure 3, a detail of construction complying with the requirements of the standards is shown to better illustrate them.

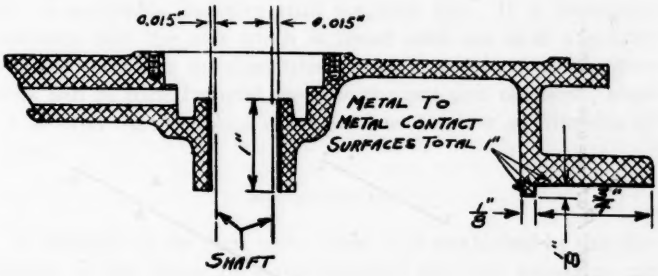

FIG. 3

VII TESTS.

While the specifications under which apparatus is purchased may set a minimum of acceptable quality, it is still necessary to check by test to ascertain whether the desired performance has been attained in the construction. Hence, explosion tests on explosion-proof units must continuously be made to insure the procurement of satisfactory material. Due to the long experience of the Bureau of Mines of the Department of the Interior in this

development, their particular interest in it, and the availability at their Pittsburgh Experiment Station of a complete and expensive testing equipment, the Navy Department depends on this government activity for the testing of apparatus of explosion-proof character.

In every case, conditions are set up which will most nearly simulate the actual service requirement. The unit to be tested is placed in a petroleum ether gas-filled compartment, and before sealing the outer chamber, the explosion-proof enclosure to be tested is carefully filled with the same explosive gas mixture that is present around it. The gas within the unit under test is then ignited, and the results are observed through glass portholes in the testing chamber. If flames or sparks issue from the unit under test, or if the gas in the testing chamber is ignited for any reason, the test is unsatisfactory.

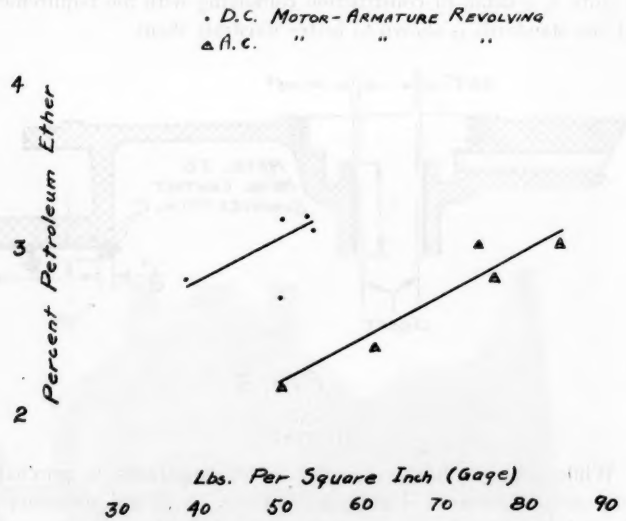

FIG. 4

While the unit is under test, a pressure device is placed within its housing, and maximum pressures are recorded for a number of different mixtures of the gas and air, and excessive pressures

become proper causes for rejection. One of the considerations in the matter of determining an allowable pressure will be brought out by an examination of Figure 4, which shows the results obtained on the test of two similar units, one of direct-current, the other of alternating current type. The pressures in the alternating current type enclosure reached much higher values, though the two assemblies were identical in their external dimensions. A contributing factor to the difference was the absence of commutator and brushes in the alternating current machine, which permitted a greater amount of unoccupied air space, and a greater volume of explosive gas.

The tests just described are applied to each new design before its approval for a particular naval use. Units built subsequent to the one tested may then be safely placed in service without explosion tests, provided similarity of construction can be proved on inspection. This may be done by checking the unit under inspection against the plans for the original unit. Units checked may have a width of joint greater than that shown on the record plan, and still be acceptable, but they shall not have less. It is important, therefore, that the unit which is tested shall not have a greater width of joint than the plans which cover it, and from which other units will be manufactured, because the test unit obviously, must not be safer than the plans which are later to serve as criterions of safety.

VIII SUMMARY.

A summary of the facts which seem to be established by this discussion of the design of explosion-proof electrical apparatus can be made as follows:

(*a*) When it is possible, under any condition, to produce a spark or flame in or near explosive gases, an explosion hazard exists. No electrical apparatus which has yet been designed, therefore, is truly explosion-proof.

(*b*) "Explosion resistant" is suggested as being more accurate in the designation of electrical equipment which can be operated in the presence of explosive gases. As this term must always be defined, it serves a useful purpose in requiring definition. This

would take the form of a statement of the limiting factors employed in its design.

(*c*) It has been determined theoretically, and has been borne out by test and experience, that a pressure relief type of enclosure should always be used to house an electrical unit operating in the presence of explosive gases.

(*d*) An airtight enclosure for electrical units operating in the vicinity of explosive gases should not be used, as, under certain conditions it can become a potential explosion hazard.

(*e*) A pressure relief designed type, when assembled with all other recognized safety precautions, may properly be designated "Explosion Resistant, Degree A," to denote that it is the best and safest available design.

(*f*) A definite and unvarying procedure must be rigidly adhered to if any type of explosion proof electrical equipment is to be maintained in that classification after it has been placed in service. In outline form this procedure is:

(1) The purchaser must specify the best design and materials and the highest quality of manufacture which it is practical to obtain.

(2) The purchaser must have conducted rigid explosion tests on the finished product, and thereafter on each modification of design. On each unit he must require meticulous inspection.

(3) The user must exercise the greatest care in the installation and operation of the unit. Continuous inspection and maintenance are necessary to insure that the explosion-proof features remain unimpaired in service.

(4) The user must not consider the unit safe in any gas concentration which is more explosive than that in which it was initially tested.

COST ACCOUNTING—A DEFINITION.

By J. B. Rhodes, Commander, U. S. N. (Retired), Member.

The author here undertakes to accurately and completely define some of the terms which the General Accounting System of the Navy has made it necessary for line officers on Bureau and Navy Yard duty to use and understand. As he points out, Accountancy and Cost Accounting do not mean the same thing. Accountancy is a profession of which Cost Accounting is a branch. Cost accounting is a system of financial records made up to serve management for control purposes, and it would seem to follow that management and accountants must "speak the same language" in order to assure a complete understanding. As the result of his Navy Yard experience before retirement, and a subsequent self-imposed training in Accountancy, Commander Rhodes believes that such an understanding does not always exist at present, and to point his argument, has clearly defined some of the confusing terms.

Every naval appropriation act for many years has contained the following mandatory clause:

"And no part of the money . . . shall be expended under Contracts hereafter made for . . . the purchase . . . from any private contractor of any . . . article, or articles, that can be . . . produced in . . . the Government Yards of the United States, when time and facilities permit, and when such production will not involve an appreciable increase in the cost to the government."

In view of the above, it is believed that officers, particularly those on duty at industrial yards and assigned to engineering duties, should have knowledge of costs and cost accounting. It is suggested that Chapter 24 of the Bureau of Supplies and Accounts Manual be read by everyone. This, entitled "Cost Inspection Under Contracts," indicates the elements of cost at private plants. For the benefit of such officers and those men in private industry

as are not familiar with the Navy's "Cost Accounting," the following has been written in the hope that it will open up discussion and that some good will come of it.

TERMINOLOGY.

Account: A subdivision or classification of a ledger, in which are collected, under the name of the person or thing affected, the debit and credit effects of transactions recorded on "primary accounting records."

Accountancy: A profession, the members of which by reason of their knowledge of (1) Accounting, (2) Finance, (3) Credits and collections, (4) Commercial Law, and (5) Income Tax procedure, are qualified to offer their services to the public.

Accounting: The science of recording and stating, with respect to the affairs of a business or an organization, the financial transactions and value fluctuations, in such a way as to show:

a. Financial condition.
b. Profit and Loss, causes or results.
c. Special and related financial facts.

Accounting, Cost: "The recording and reporting of charges by purposes, *i.e.,* under the . . . classification of objects prescribed by the Navy Department, and for all output work of the plant, by jobs or other units. Incident to the computation of costs of production is the determination of the method and amount of the distribution of plant maintenance charges to output as the overhead element of its cost." (Manual for accounting officers, 1925, p. 148.)

Accounting Records—Primary: Any paper on which are recorded original facts of financial transactions. These take various forms from the day book or journal to tickets, vouchers, etc. In Navy Yards Time Cards and Stub Requisitions are used. It is to be noted that the total of time cards must equal the total payroll for the class of labor using time cards.

Accounts: (Physical classification—Navy).

0 Miscellaneous labor and consumable supplies.
1 Losses and gratuities.
2 Land and appurtenances: Repairs to.
3 Buildings and structures: Repairs to.

4 Miscellaneous equipment: Cost of new and repairs to old.
5 Plant appliances: Repairs to.
6 Machinery and machine tools: Repairs to.
7 Portable power tools: Cost of new and repairs to old.
8 Loose and hand tools: Cost of new and repairs to old.
9 Supervision.

Balance Sheet: A statement of financial condition of a business showing the facts in regards to Assets, Liabilities and Capital as of a certain date. It is made up from double entry books of account. Capital is determined from the Ledger rather than by comparison of Assets and Liabilities.

Burden: The burden is that part of the cost of manufacturing which is not directly productive. Generally speaking, burden is indirect cost of manufacture and is composed of items that do not vary with variations in output.

Capital: From the accountant's point of view, is the proprietor's interest in the business as determined by the excess of Assets over Liabilities.

Control Accounts: Accounts maintained in general ledgers, to which are posted periodically the totals of entries in subsidiary ledgers, made from primary accounting records. Making a credit in a ledger under one account and an equal debit under another account the ledgers will always balance.

Cost, Cost Price: The terms "cost" and "cost price" are frequently regarded as synonymous but, although in certain cases this may be true, there is a distinct difference. Both are connected with the acquiring of something of value but cost price usually includes also the idea of disposal of that thing, or at any rate, a basis of disposal.

The price is the exchangeable value of a commodity and means the total amount which a certain thing has cost up to a certain time. It frequently includes the amount paid for an article together with other charges necessary to its acquisition, such as freight in the case of merchandise, or legal expenses in the examination of title in the case of real estate.

"Cost" does not involve the idea of disposing of the article. It is simply the expenditure of money or services or their equivalent. It is a far more general term and when used in accountancy is

generally modified, as in the expression "cost at plant," "C. I. F.," "Cost of labor" or in such expressions as "Work done at the public cost."

Cost, Industrial: A term used in Navy accounting which means the "cost of each job or article manufactured" . . . as "determined by including as elements of cost the direct charges to the job and also a proper proportion of the maintenance and operation of the shops and general expense of the industrial portion of the yard, depreciation of property, and disability of employees."

Cost of Goods Sold: Equals material on hand at beginning of an accounting period, plus material purchased, plus salaries and wages, plus other costs, less material on hand at the end of the accounting period. "All costs incurred until the product is available for sale. Includes all production costs in a manufacturing industry." (Paton's handbook, page 24.) Note the exclusions under Deductions on the Report of Income for Tax purposes.

Credit: When used as a noun, indicates an amount placed on the right side of a ledger account. When used as a verb, indicates the posting of an amount to the right side of a ledger account. (For debit, substitute left for right in the above definition.)

Depreciation: The basic idea conveyed by this word is indicated by its derivation—de, down, and pretium, price; that is a reduction in price or value.

Depreciation is loss in physical or functional value of physical property, other than wasting assets, due primarily and chiefly to ordinary wear and tear which has occurred theoretically in the past and is not offset by adequate repairs and/or replacements. Obsolescence and inadequacy are included by regulatory bodies and taxing authorities as contributory causes, but it is more in accordance with fact to separate these two elements from ordinary wear and tear on the ground that the loss incident thereto does not usually accrue and cannot be foreseen with any degree of accuracy. Depreciation, however determined, is at best only an estimate.

Expenses, Indirect: Expenses for overhead, departmental costs, etc., which enter into the cost of manufacturing in addition to the direct expenses.

Expenses, Manufacturing: The cost of manufacturing other than material consumed and direct labor. It includes all the indirect

expenses called, in Navy Accounting, General Expense and Shop Expense (except Military Expense), plus items of rent, taxes, insurance, etc.

Expenses, Selling: All expenses incurred in selling, such as salesmen's salaries, commissions and expenses, advertising, selling-department salaries and expenses, samples, etc.

Expenses, Shop: In Navy Accounting, the expenses applying to the elements listed under Accounts—(physical classification of) are collected for each Production Unit (Shop).

Expenses, Direct: "The cost of labor and material and sometimes steam, power and electric current directly consumed in the manufacture of a product, as distinguished from overhead and other indirect costs which are pro-rated among several departments or subjects."

Expenses, General: Those expenses of a concern which do not fall under the heading of trading, manufacturing or selling, but apply to the general management. Sometimes they are shown in the profit and loss statement as a separate group and sometimes they are included in the administrative expenses.

This term is used in Navy Cost Accounting to include all expenses not included in shop expense. The groups of accounts under general expenses (0) are:

00 Miscellaneous (Grounds, water fronts, communications, fire protection).
01 Supply.
02 Yard Transportation.
03 Power.
04 Administrative.
05 Building Ways.
06 Central Tool-Shop.
07 Military.

Job Order: The paper on which is written an order to undertake work. This paper may serve as a sheet for "Scheduling work" as a cost sheet for a ledger account, etc. The information to be shown on the paper is set forth in Navy Accounting Instructions and is standard for twelve industrial yards.

Journal Entry: Every entry in a journal is based on the principle that there are two sides to each transaction, both of which are

indicated in every journal entry. One or more accounts are charged with a certain total amount while one or more accounts are credited with items which aggregate the same sum.

Journal Voucher: Used in Navy Accounting, it is to be noted that Journal Voucher No. 1 shows credits to the following accounts—(1) Overhead not charged to Appropriation. (2) Pay and allowances, officers and enlisted men. (3) Depreciation on Plant. (4) Disability.

Ledger: Secondary accounting records, classified by accounts with persons and things to which postings are made from "primary accounting records" or recapitulations and summaries of such primary records.

Liability: A legal financial obligation on the part of a person or an organization to pay a certain sum of money to another person or organization, at a determinable future date.

Labor—Direct: "Wages paid for labor directly applied to the articles contracted for, or the component parts thereof, and includes allowances for authorized overtime and approved premiums or production bonuses." (Bureau of S. & A. Manual Art. 2403, par. 3.)

Manufacturing Account: An account showing:

Dr.	Cr.
Work in process inventory, beginning.	Work in process inventory, ending.
Material consumed.	Balance, Cost of manufactured product made. (Transferred to manufactured product account.)
Direct labor.	
Manufacturing expense.	
Indirect Labor.	
Indirect Material.	
Indirect Expense.	

Material: Tangible assets used in manufacture and, in the case of direct material, becoming a part of the product. Indirect material is used for the purposes set forth in the various expense accounts. At the end of an accounting period, material on hand is shown as Inventory (Raw material, work in process, contract material, etc.).

Overhead: (Synonym "Burden") "The indirect labor and other manufacturing expenses and the general and administrative expense of the contractors." (Bu. S. S. Manual, Art. 2403, par. 5.)

(*b*) "All overhead charges . . . classified by the group, section or shop for which incurred" are "added to the cost of the productive work by means of the shop rate (which is a partial overhead rate). An additional overhead rate representing the additional overhead, including pay for officers, clerks, draftsmen, and depreciation, disability, etc., is computed for the yard as a whole and applied to the estimated indeterminate charges on reports of expenditures and job costs in order to obtain the total industrial costs." "Bu. S. & A. Manual Art. 602, par. 1 (b)."

In addition to the "Total Industrial Cost" as obtained in a Navy Yard, a private plant includes, in its "Indirect Factory Expense" Accounts, Insurance, Taxes, Rentals (obtaining factory costs) and in its "selling Expense" and "General Administrative Expense" accounts, allowances, discounts, advertising, legal expense, etc.

Using double entry bookkeeping, the charges made to Expense Accounts by private industry are balanced by credits made to an account showing a credit balance. As the Navy "Expenses" spends no money and incurs no liability for any of the above there is no way to include these elements as a part of Navy industrial cost.

Profits: "Net Profits" is "the realized increase in 'net Assets' during a fiscal year or other accounting period." "Gross profits" in a manufacturing business is the excess of the value realized, on sale of the product, over the "cost of goods sold." "Net profits" should be qualified when anything other than "Net income" is intended. The terms "Net Profits on operations," "Net profits before Income Tax," etc., are in common use.

Production Unit: A machine and its operating crew or an operating crew and their tools or any combination of the two. Management determines its organization and delegates responsibility. Cost accounting determines the facts in regard to the values expended by responsible heads of production units.

Recapitulation and Summaries: Daily balances may be obtained by comparing the total debits with the total credits. This applies particularly to time tickets and payroll. The daily summaries are

totaled at the end of a pay period. Other recapitulations and summaries are made depending upon the mechanical devices in use. The terms are usually qualified to show the element for which totals are made. The term means a sheet to which are posted, at designated times for ultimate posting to ledger accounts, the amounts of money shown on primary accounting records of labor, material and expense.

Ticket—Time, Labor, Unit, Etc.: Navy Accounting Instructions require the use, as a primary accounting record, of a "time card" which is an individual ticket, signed by the employee and the supervisor. Such tickets are in general use by industries keeping "job costs." The tickets are designed to suit the machines used for sorting, tabulating, etc., and show pertinent information of product and production.

Work in Process: The partially finished product in the shops of a business or an organization. Modern accounting systems show this at a value, in the inventory, of labor, material and indirect manufacturing expense used in its partial finishing. It is with a job order system, the total cost, at a certain date, of the open job orders.

Point 27 of the Federal Reserve Board's proposal for uniform accounting is:

"It may be well to reiterate that interest, selling expense, and administrative expenses form no part of the cost of production and therefore should not be included in the inventory in any shape."

THE PROBLEM OF THE PHENOL RESINOIDS.

By T. E. Cassey, Member.*

As Mr. Cassey notes in his discussion, molded phenolic condensate, or phenol resinoid, is a structural material which, in recent years, has advanced to a position of importance in industry almost comparable with metal, wood, and stone. Its excellent insulating qualities for electrical applications gave the impetus to its development, but recently its usefulness for small, light, and handsome cases has carried it far afield from the electrical industry in which it was born. The rapidly increasing number of applications to which it is adapted, and the wide difference of opinion which exists among its manufacturers as to the proper methods for producing it in its various forms, makes the article timely, and of particular interest to the engineers who have to use the finished product. The attempt of the Navy Department to urge industrial production to a high and uniform standard has created a real problem in specification and supply, and it is only during the last few months that a concerted and cooperative effort on the part of buyers and sellers seems to give promise of a satisfactory solution. It is hoped in a later issue of the Journal *to develop some of the details of the problem incident to mold design and manufacturing technique, the complexity of which will become apparent, on a perusal of this article.*

Possibly no equipment problem involved in the construction of naval vessels in recent years had demanded the attention given to the application of phenol resinoids to the field of electrical installations. Although phenol resinoid materials have been used in electrical installations in naval vessels for many years, little was heard

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about the product, and it has been only very lately that these materials have forced their way into the position of prominence which they now hold.

In commercial industry, phenol resinoids have, for specific purposes, replaced practically all known metals and most insulating materials, and successfully. One engineer, in referring to this rather astonishing development, described the new product in the following very pertinent paragraph:

"When a new class of material begins to rank with metal, stone, and wood as one of the four principal materials of construction, it becomes properly a subject for thoughtful consideration by engineers. In contrast to each one of these older substances it possesses inherent advantages and limitations. It is something distinct, and, therefore, can stand alone, not as a questionable substitute, but as an auxiliary new material having a technical personality of its own."

From the above, one must conclude, at the outset, that this material must have not only a remarkable assortment of properties, but also an equally varied adaptability.

One of the major considerations which has contributed to the rapid extension of the use of phenol resinoids is the ability of these materials to resist those normal conditions—heat, moisture, acids and alkalies—which tend to break down the structure of so many materials. In their molded form, their facility of production, based on the plascticity of the raw materials, must not be overlooked.

These manufacturing processes are the factor which makes possible the conversion of the raw materials directly to the desired final shape, with practically no loss of material and at an expenditure of time and labor which is usually only a fraction of that which would be required if the part were shaped from rough stock by machining operations.

Phenolic resins in their early relation to naval construction, were rather broadly referred to as "molded insulation." More recently, with specific reference to the molded forms, the term "molded phenolic material" has been used. Neither of these names is particularly appropriate. In appreciation of the physical resemblance and the chemical dissimilarity of those new materials from the natural resins, the commercial world has adopted the name "phenol

resinoid" as a distinctive designation for these materials. This name appears to be the better technical description for this class of materials.

Until recently, the application of molded phenol resinoids to naval installations was limited to such uses as interiors or "insulating bases" of electrical fittings, connection strips, lamp sockets, receptacle plug tips and such similar small items where the pieces were well supported within a stronger metal structure. At the present time, molded phenolic resinoids are being utilized in the design and manufacture of complete enclosures (boxes and covers) of electrical fittings, gauges, meters, clocks, etc., replacing brass or aluminum heretofore used. Advantages to be gained by the use of these molded phenol resinoid enclosures over metal housings, particularly as concerns electrical applications, are briefly as follow:

Greater dielectric strength.
Elimination of grounds.
Elimination of corrosion.
High thermal resistance.
High resistance to the effects of sea air, acid fumes and oil.
Painting not required.
Little, if any, cleaning required.

Molded phenolic resinoids are commonly referred to as "Bakelite," the name being derived from the name of the inventor, Dr. Leo Hendrick Baekeland, who first produced the material in 1906. This material is a synthetic resin, the manufacture of which involves the interaction (condensation) of pure phenol and formaldehyde solution. The preparation is classified as a formaldehyde-phenol resin and further identified as of the initially soluble or heat hardening group. It is odorless, tasteless and inert. In its raw or primary state, phenol resinoid is quickly softened by moderate heat and is soluble in alcohol or acetone. A very brief exposure to greater heat sets up a further chemical reaction and causes it to solidify to a state which will not permit of remelting and which is unaffected by solvents. This change is termed "polymerization." Thus the material is thermo-plastic, and moreover is heat-reactive, and heat transformed. This resultant resin is incorporated with a filler such as wood or asbestos flour, or with a fibrous material

either in shredded or sheet form, thus forming preparations known as resinoid molding materials.

Resinoid molding materials have been defined as "general utility, partially converted, intermediate, raw materials adapted to final conversion in dies operated with heat and pressure." These materials may be in the form of dry powder, of granular form, or of a flaky consistency, dependent upon the nature of the filler. For purposes of convenience in loading, these materials may be preformed into tablets or sheets. The proper amount of material for the molding operation is obtained by measure of weight, or by the use of a measuring or filler plate forming a part of the mold. In the case of preforms, the amount of material is predetermined in the preforming process.

The molding of phenol resinoids differs from the routine production of many industrial items in that the human element may more seriously affect the characteristics of the product. The operation of molding these materials is a combination, or what may be termed a resultant of the following essential considerations. Undue variation in any one of these will destroy the properties demanded:

An exact amount of a definite material.
A definite pressure.
A definite temperature.
A definite time.
In some cases, controlled cooling.

The types and classes of phenol resinoid molding materials are innumerable and no attempt will be made to describe or classify them. It is sufficient to state that properties can be obtained with these materials through the medium of molding processes, as diverse as the number of materials themselves. To illustrate, wood flour filled materials, properly molded, will have properties within the following limits and varying according to the type of material: specific gravity, 1.35 to 1.44; tensile, 6000 to 9000 pounds per square inch; flexural, 8800 to 10,000 pounds per square inch; impact per inch square, 1.40 to 1.75. Mineral filled materials will have properties differing from wood flour materials as follows: specific gravity, 1.78 to 1.98; tensile, 4000 to 6000 pounds per square inch; flexural, 5000 to 10,000 pounds; impact

per inch square, 1.70 to 6.20. Impact resisting fabric base materials have still another set of properties which lie within values as follow: specific gravity, 1.37 to 1.39; tensile, 6200 to 7000 pounds per square inch; flexural, 9000 to 10,000 pounds per square inch; impact per inch square, 2.28 to 29.0. From an examination of the foregoing figures it will be seen that characteristics can be obtained to meet almost any requirements. It is important to notice the great increase in impact strength present in the fabric base materials. It should be understood, however, that the molding technique enters into the creation of these finished materials and only when the molding technique is correct can the expected properties be obtained. It is for this reason that molding processes and mold designs play such an important part in the production of phenol resinoids, particularly for naval installations where guarantees of performance of finished articles are required.

The molding of phenol resinoids bears a resemblance to the die casting of metals but differs in some essential details. As applied to metals, the term "die casting" is defined as the art of casting molten metal into steel dies. In the case of resinoid hot-molding, the operation differs from "die-casting" in the usual sense of the term, as the operation relies essentially upon mechanical pressure; also the charge is solid instead of liquid. Under the hot-molding operation, the material is not only set up in a new physical form, but chemically at the same time is converted into a new material.

The powder materials are compressed, in the molding process, to about 40 per cent of their original volume, the material suffering no appreciable loss in weight during the molding process. In other words, the raw material has approximately 2½ times the bulk of the molded piece. In the case of the high impact materials, having fabric base, this bulk factor increases to above 5 to 1. The question of bulk factor is one of considerable importance in the design of molds as sufficient volume must be provided above the mold cavity to permit loading the mold with the required amount of raw material. With well-designed molds and proper technique, molding accuracy within 0.002 inch is obtainable.

Pressure may be considered, perhaps, the most important consideration in molding phenolic materials as the pressure applied to the material influences strength. The effective pressure also causes

the raw material to fill out the mold cavity, and affects the time of cure and the finish of the molded piece.

A minimum of 2000 pounds per square inch effective pressure on the molded part is used, based on the horizontal area of the piece. This figure applies in the case of comparatively flat pieces only. For pieces with high side walls requiring a deep draw, an additional seven hundred pounds per square inch is allowed for each inch of wall height. These figures are only approximate and of course applicable to materials of normal strength and plasticities. Higher impact strength materials require greater pressure. Required pressures are affected by the design of the mold, and so we have another principal consideration of mold construction, *i.e.*, sufficient strength and ruggedness to withstand the enormous pressures incident to the molding operation.

Pressure also greatly influences the rate of cure. With high pressure a stiffer material can be used and stiffer materials under the same pressure, in general, cure faster than softer types.

Pressure causes the material to flux more rapidly and thoroughly, and, at the same time, causes a quicker transfer of heat units from the mold to the material due to the closer contact of the mold and the compound under the higher pressure.

Proper cure is of great importance as effecting the shrinkage of the finished piece. Shrinkage stops when the material is thoroughly cured, whereas lack of proper cure permits the shrinkage to continue to some extent. As most industrial applications of molded phenol resinoids require the finished pieces to be held to very close dimensional tolerances, it can be readily seen that pressure merits the most careful consideration and supervision in the production of properly molded pieces. It is generally accepted that parts shrink seven to eight thousandths of an inch per inch on being taken from the mold. This shrinkage, of course, is allowed for in designing the molds. It is possible to reduce this shrinkage by leaving the piece in the mold for a long cooling period after molding. Another method is by the use of " shrinkage fixtures " on which the pieces are mounted after their removal from the mold. The first method is impracticable from an economic standpoint. The second method is in general use where shrinkage of the piece will cause distortion.

Of almost equal importance to pressure is the heat applied to the material during the molding operation. The function of the heat is twofold. First, to soften the material and put it in a plastic state so that the pressure may force it throughout the mold cavity and flux it into a solid homogeneous mass. Second, to cause the polymerization of the resin which results in the material curing and hardening into an insoluble, infusible mass. Under too low a temperature the molding compound does not soften sufficiently to properly fill out the mold cavity.

The effect of heat on cure is also important. As may be supposed, a certain number of heat units are required to transform a given quantity of molding compound from the basic form to the finished molded state. The quicker these heat units can be transferred from the mold to the material, the shorter will be the time required. To get the quickest results the mold must be hot to start with and sufficient heat be available for immediate use. The importance of heat from an economic standpoint will be realized when attention is invited to the fact that the difference in curing time (which determines the production from a mold) may be a hundred per cent between conditions of proper and improper heat application.

Steam has proved to be the most practical heat medium for phenol resinoid molding due to the fact that it not only supplies heat units as it reduces in temperature, but also gives them off in far greater quantity in condensing to water because of the latent heat of vaporization.

The molding time for different resinoid materials covers an appreciable range. Many factors enter into the determination of the proper molding time, principally, however, molding time depends on the weight and structure of the product.

Molds used in the production of molded phenolic pieces are probably as numerous and diverse in their construction as there are classes of phenol resinoids available to the molder. In fact, it is the exception when two successive molds are built alike even by the same company and for the production of the same piece. Not only are the ideas of the various molding companies somewhat divergent when it comes to mold construction, but it is rare that even two persons of the same organization will agree in all details as to the

construction of any particular mold. Various considerations affect mold design, other than the mechanics of the particular piece, such as differences in plant equipment, styles of presses, steam pressure, plant administration, labor conditions, and other economic reasons.

The various kinds of mold equipments used in commercial fields may be grouped and classified with respect to their general application and relation to the industry. For the purposes of classification and identification, we may consider molds under the headings of "Method of Heating," "Style," "Class," and "Type."

As regards the principle of heat transfer, molds may be divided into two general groups:

Direct heated.
Indirect heated.

With respect to the general method of handling (loading and pulling), molds may be considered to be of the following styles:

Hand.
Semiautomatic.

Based on the number of cavities, molds may be classified under the following classes:

Single cavity.
Multiple cavity.

As regards the basic principle involved in the compression or what may be termed the physical action of the plastic during molding, molds may be classified under the following types:

Flash.
Positive.
Extrusion (Transfer).
Blowing.
Special.

Flash molds are further divided into the following "sub-types":

Single (Overflow).
Stripper-plate.
Filler-plate.
Subcavity.

Likewise, positive molds are divided into the following "subtypes":

Truly.
Landed.
Semi.
Floating Chase.
Split follower.

The selection of a complete designation for a mold involves, therefore, the proper selection under each of the above classifications. As an example a complete mold designation would be "hand, single cavity, flash, filler plate, direct heated," or "semi-automatic, multiple cavity, positive, landed, indirect heated," etc.

It can readily be seen from the foregoing that the selection of the proper mold classification for a particular design requires considerable knowledge of the various mold characteristics. As is true for any form of equipment, there is always the best type of "machine" for each job; likewise in the molding industry there is a best type of mold equipment for each particular design of molded piece.

The molded phenolic industry, even in its relatively short life, has reached a remarkable state of development in its molding technique, but has yet to reach the stage whereby it can assure the customer that this technique will produce a uniformity of product commensurate with the knowledge available on the subject.

The production of phenol resinoid pieces is not to be considered as merely a series of mechanical functions of loading the mold; obtaining the required temperature and then applying an academic pressure to the mold cavity for a stated time. Many difficulties arise in turning out these molded products, even under the most careful supervision on the part of the molder. The wrong material may be substituted, the molding temperature or pressure may get out of control, the mold may heat unevenly, the workman may speed up on the time of cure or he may slip up on the amount of material he is using; the breathing of the mold may be not quite right, the material may not flow properly, and the piece may be poorly designed from the molder's viewpoint, to start with. All these things can happen and many more. With improper conditions creeping in, the molder will be faced with a product showing poor

finish, blistering, excessive shrinkage, warpage or lack of uniform density; one or all of these may occur, resulting in excessive rejections. For Navy work these conditions are accentuated, and the possibilities for rejection become correspondingly greater, for the molder must not only satisfy himself, but he must submit his finished pieces to very exacting laboratory tests to determine physical and chemical characteristics, and in addition, he must have these pieces pass a very definite dimensional examination.

Commercial molding procedure does very well in the routine production of the vast number of commercial articles, ranging from toothpaste caps, bottle caps, house wiring fittings, face plates, lamp sockets, ash trays, etc., where high production and low cost dictates the use of semi-automatic molding equipments, and where only superficial inspection is necessary. Even in the more serious type of industrial molding production, where strength becomes of greater importance, and where the production is slowed down to obtain greater security, we do not find the rigid demand for the high uniformity of the product which exists for the Navy production.

For industrial production, the molder can select the most suitable material, designing his mold for the particular piece with due regard to the production he must run. Moreover, he may train an operator to produce this piece who will, in time, become expert in this particular production. Tests of the product are simplified, as they constitute only a check on a continued flow of similar pieces produced under almost identical conditions. This type of molding is the ultimate in the art, producing as it does a surprising uniformity in the manufactured output.

For the production of molded phenolic resinoid pieces for naval use, we have a different picture to present. Industrial molding methods have not been too successful in the production of these molded pieces, which must meet conditions much more severe than in similar commercial applications.

A few years ago it was found that large quantities of phenol resinoid pieces, over which the Bureau exercised little or no control, were finding their way into naval installations. Further investigation disclosed that even in the case of N.S.A. contracts, molded pieces were being accepted about as the molder wished to produce

them. Being faced with the necessity of award to the "low bidder" for this material, and at this time having no adequate specifications covering mold equipment, it was natural that the quality of the product as well as the molds themselves would not be all that could be desired.

Upon the enforcement of rigid test requirements governing the acceptance of molded pieces, with consequent increased molding pressures, longer cure, etc., the Department's mold equipments began to fail dismally. Production slowed down, rejections occurred more frequently, and the Department's troubles with phenol resinoids became serious. Molders were penalized by their use of Government owned molds which they did not build and which did not suit their presses or molding technique. These molds in many cases were badly battered by previous usage, pieces were missing, and fractured parts appeared that had been repaired by joining broken pieces together with machine screws or by poor attempts at welding. To make matters worse, many molds distorted or "carried away" under the molder's attempt to meet the ever-increasing requirements of an intensive inspection procedure.

Substitutions of raw materials appeared, and "dilution" was also a practice that entered into the picture. These faults were not due to the desire of the molder to cheapen his product, but were caused by attempts of the molder to get out his production under the unsatisfactory conditions existing at that time.

Mold designs for the production of Navy pieces are now being improved and standardized. Molders are cooperating with the Bureau in this work to the benefit of all interested parties. With good mold equipments available, which are covered by adequate detail drawings, no reason will exist to dilute the raw material or to attempt a substitution.

Many factors still contribute to the difficulties experienced in Navy purchases of phenol resinoid molded pieces. None are insurmountable, and much has been accomplished recently to alleviate the unsatisfactory conditions and arrive at a basis of mutual understanding. Some of the contributing causes for difficulties experienced in obtaining molded pieces may be given as follows, not all of which, of course, apply in any one case:

(*a*) Lack of knowledge on the part of the molder of the underlying reasons for the special requirements for materials used in construction of naval vessels.

(*b*) Lack of care in studying the Navy Department requirements for information to be furnished with bids, as embodied in schedules issued for purchases.

(*c*) Too slow a development of the Navy Department Specifications for phenolic materials and mold equipments resulting in these not being completely abreast of developments and advances made through successive purchases.

(*d*) An attempt in the Navy Department Specifications to satisfy the widely varying design problems with too few materials.

(*e*) Lack of understanding of the "Navy Approved List."

(*f*) So-called "brand identification tests."

(*g*) Navy inspection.

(*h*) Dimensional check of pieces.

(*i*) Lack of requirements for physical tests to determine characteristics of the molded product.

(*j*) Government owned molds.

(*k*) Damage to Government molds.

(*l*) Requirements for building molds purchased for delivery to the Government.

(*m*) Preparation of drawings showing designs of molds for delivery to the Government.

Much regarding the foregoing can be said from both the viewpoints of the Government and the molder. Undoubtedly, each has strong opinions on all of these troublesome points. Conferences have been held between molders' representatives and representatives of the Navy Department, to iron out these difficulties. As previously stated, a great deal has already been accomplished, and it is felt that as the molder comes to realize that the motive behind the Navy's various requirements is only an attempt to obtain the ultimate that the molding industry can produce, then a ready solution will be found that will benefit all parties concerned.

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MISCELLANEA OF ITEMS OF INTEREST TO NAVAL ENGINEERS.

Selection of Colors for Signal Lights.
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—Combustion, New York, N. Y., November, 1936.

Cruising Diesel Engines in German Warships.
—The British Motor Ship, London, England, December, 1936.

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—Boston Navy Yard News, November, 1936.

Performance of the Ljungstrom Noncondensing Turbine Locomotive.
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—Machinery, New York, N. Y., January, 1937.

Detecting Cracks at Rivet Holes.
—Combustion, New York, N. Y., December, 1936.

Jane's Fighting Ships, 1936.—A Book Review.
—Shipbuilding and Shipping Record, London, England, December 30, 1936.

Relative Prices of Boiler Oil and Diesel Fuel.
—The British Motor Ship, London, England, January, 1937.

For Scholarly Readers.
—The Industrial Bulletin, Arthur D. Little, Inc., Cambridge, Mass., January, 1937.

Germany's Latest Motor Battleship.
—The British Motor Ship, London, England, January, 1937.

EDITOR'S FORUM.

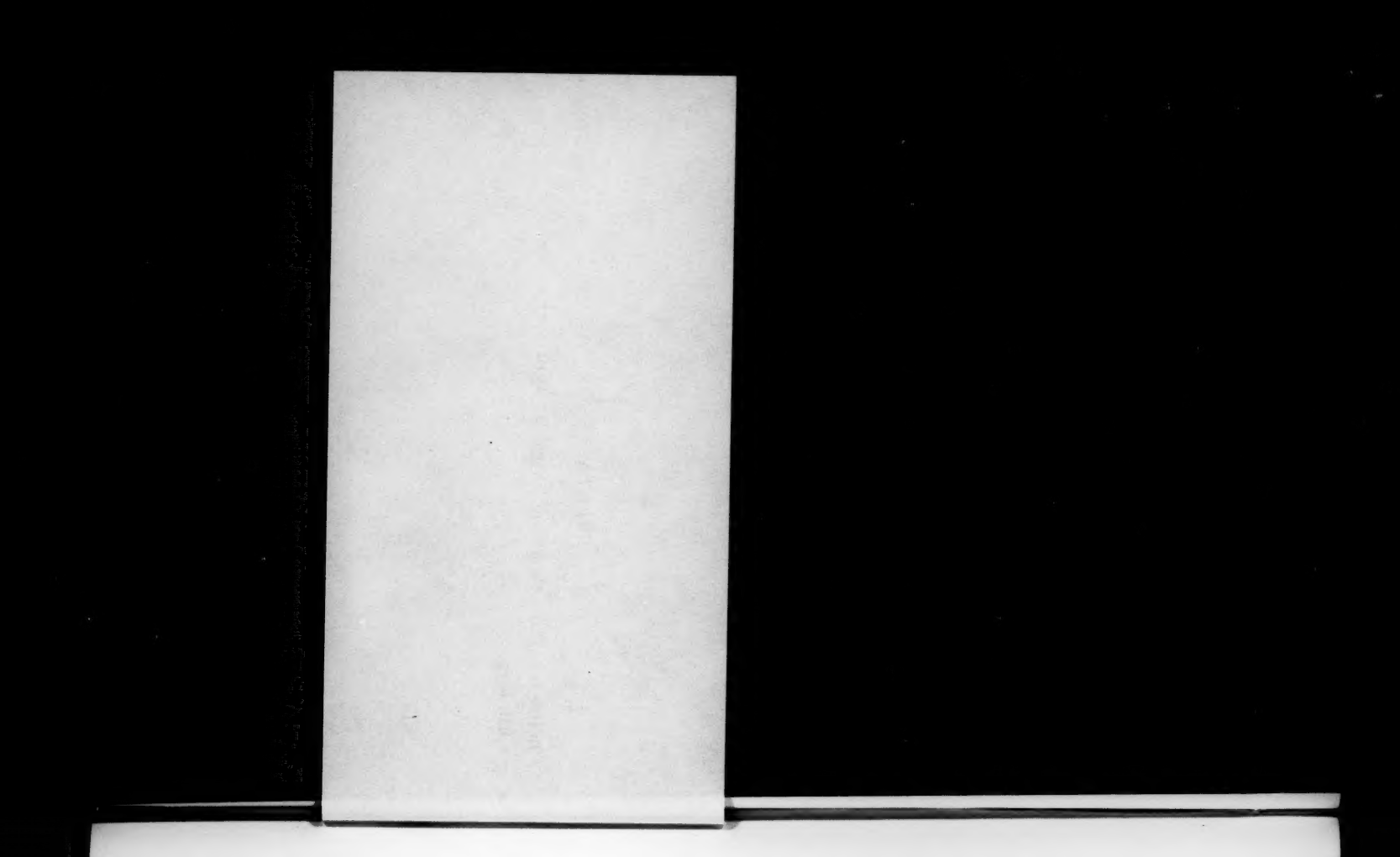
The Editor takes advantage of this opportunity to invite the attention of the membership to the forthcoming Annual Banquet of the Society, which will be held at the Willard Hotel, Washington, D. C., on Thursday, April 22, 1937. Please note the date. Nearly eight hundred members and their friends attended last year's affair, coming to Washington from all parts of the country. It is desired to surpass that record attendance this year, if possible, and every effort is being made to better the excellent and enjoyable programs of entertainment, which have made the banquets outstanding events in the engineering world. So come and bring your friends. Announcements will be mailed out shortly, and those who expect to attend are urged to secure their reservations as early as possible. The Committee on Arrangements hopes to be able to close the books and complete a final seating arrangement two days before the date of the banquet, in order to minimize the last-minute confusion which ensues when so large a number of out-of-town guests must be properly cared for. Your cooperation is requested.

STEAMOTIVE.

This article, taken from the Mid-December issue of Power, New York, N. Y., is a condensed version of the paper read at the Annual Meeting of the American Society of Mechanical Engineers, at New York, November 30 to December 4, 1936, prepared by Messrs. E. G. Bailey of the Babcock & Wilcox Co., New York; A. R. Smith of the General Electric Co., Schenec-

ERRATA.

In line four, Editor's Forum, change 22 April, 1937, to read 15 April, 1937.



tady, N. Y., and P. S. Dickey of the Bailey Meter Co., Cleveland, Ohio. This all-American invasion of the High Pressure High Temperature field of boiler construction will be of interest to marine, locomotive, and power plant engineers alike.

For the past two years it has been rumored that General Electric and Babcock & Wilcox were developing a unit power plant of about 1000 horsepower. This development work was shrouded with great secrecy, but the veil has now been lifted to reveal the new "Steamotive" unit. It was described by E. G. Bailey, A. R. Smith and P. S. Dickey.

The developmental Steamotive unit is oil-fired, designed for an output of 21,000 pounds of steam per hour at a pressure of 1500 pounds and 900 degrees leaving the superheater.

No serious defects were encountered in any of this equipment. During tests the complete unit operated 950 hours, much of which time was at continuous maximum rating with long periods under extremely variable load conditions. Combustion rates exceeded 400,000 B.T.U. per cubic foot per hour at peak, and 375,000 under continuous load. The unit operated over an output range of 10 to 1 under complete automatic control.

The flame and gas pass horizontally through the completely watercooled furnace, which is approximately 3½ feet wide, 3½ feet high, and 7½ feet long from the burner wall to the boiler-screen tubes. The gas then passes up and back with a 180-degree turn into the superheater, flowing around a separator to the economizer, air heater and up to the stack. Air for combustion leaves the blower at about 60 inches water pressure, passing to flues intersecting the stack and down around the air-heater tubes to the oil burner. There is no induced-draft fan.

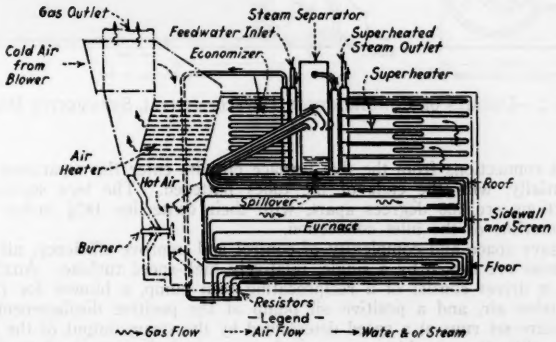


FIG. 1.—FLOW DIAGRAM, DEVELOPMENTAL STEAMOTIVE BOILER.

Feedwater enters the economizer inlet header, from which it flows through 29 horizontal coils to the outlet header. From the outlet header the flow is divided into five circuits, all five of which form the floor, side and roof of the furnace as well as two sets of loops forming a boiler screen. All steam

is generated in these five furnace and boiler circuits and enters a separator with a surplus of about 400 pounds of water per hour in each circuit. From the separator the dry steam goes through the superheater and directly to the main turbine. Water from the separator is called "spill-over" and passes through a heat exchanger to the hotwell, where it mixes with condensate and is re-fed to the boiler.

The superheater occupies only about one-third of the available space. Roof, rear wall and side walls of the cavity in the rear of the superheater are lined with closely spaced superheater tubes forming a radiant section, the purpose being primarily to protect the inner casing plates from excessive gas temperature. Superheater tubes are KA2S alloy steel (18 per cent chromium, 8 per cent nickel), supported by alloy-steel rods hung from roof with springs to take care of expansion.

The air heater is made up of 1515 tubes 2 feet 4 inches long. The tube ends are welded into steel tube sheets. Gas flows inside the tubes and air flows outside.

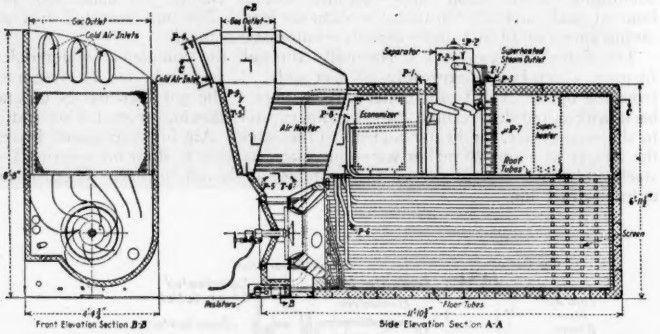


FIG. 2.—DETAILS OF CONSTRUCTION, DEVELOPMENTAL STEAMOTIVE BOILER.

Inlet connections from the five furnace circuits enter the separating drum tangentially, with the ends of the tubes flattened. The two steam-outlet connections are 180 degrees apart, with their centerline 18¼ inches above the centerline of the inlet connection.

To save space and complexity of control and improve efficiency, all boiler auxiliaries are driven by a single, relatively high-speed turbine. Auxiliaries which it drives consist of a reciprocating feed pump, a blower for furnace combustion air, and a positive oil pump of the positive displacement type. The entire set runs at a speed determined by the steam output of the boiler, with modifications to blower output by means of dampers, and to fuel-oil output by means of a bypass on the fuel-oil pump.

The combustion-air blower is a centrifugal compressor having a maximum discharge head of about 60 inches of water. The boiler-feed pump is a single-acting 5-cylinder piston pump running at a normal speed of about 800 R.P.M. with pressure lubrication of the crankshaft pins, connecting rods and cross-head wrist pins.

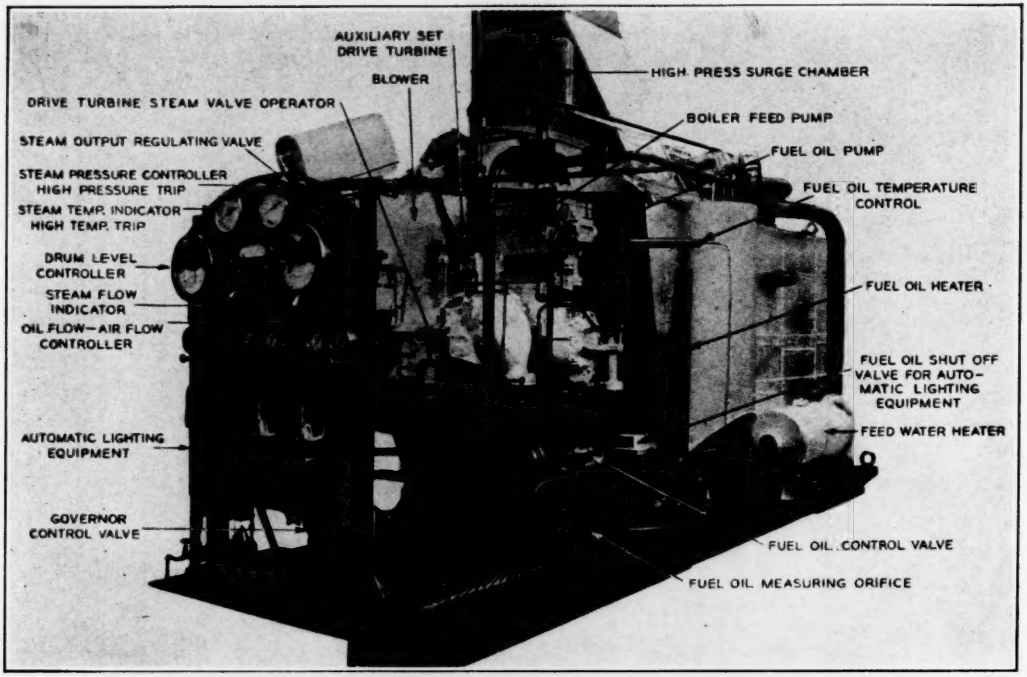

AUXILIARY SET DRIVE TURBINE
BLOWER
DRIVE TURBINE STEAM VALVE OPERATOR
STEAM OUTPUT REGULATING VALVE
STEAM PRESSURE CONTROLLER HIGH PRESSURE TRIP
STEAM TEMP. INDICATOR HIGH TEMP. TRIP
DRUM LEVEL CONTROLLER
STEAM FLOW INDICATOR
OIL FLOW—AIR FLOW CONTROLLER
AUTOMATIC LIGHTING EQUIPMENT
GOVERNOR CONTROL VALVE
HIGH PRESS SURGE CHAMBER
BOILER FEED PUMP
FUEL OIL PUMP
FUEL OIL TEMPERATURE CONTROL
FUEL OIL HEATER
FUEL OIL SHUT OFF VALVE FOR AUTOMATIC LIGHTING EQUIPMENT
FEED WATER HEATER
FUEL OIL CONTROL VALVE
FUEL OIL MEASURING ORIFICE

FIG. 3.—GENERAL ARRANGEMENT OF EQUIPMENT, DEVELOPMENTAL STEAMOTIVE UNIT.

In view of the limited amount of water and heat storage in the Steamotive, and since all natural circulation is eliminated, it is of utmost importance in operating this unit that water be fed as nearly possible equal to the rate of steam output plus "spillover." The desired rate of water flow is established by measured indications of total boiler steam flow and separator drum level. Spillover water delivered into the separating drum is maintained constant at all outputs.

The auxiliary set is designed to provide an excess of air and oil at any given feed-pump speed, and the automatic-control equipment is arranged so that the necessary throttling of both is provided to maintain a constant steam pressure at the boiler output. In addition, the ratio of fuel and air is closely controlled in accordance with metered indications of each, to maintain minimum allowable excess air required for good combustion.

The oil burner is provided with a propane torch with dual spark ignition and with a photo-electric flame indicator. A 3-way valve which shuts off automatically oil to the burner and recirculates the oil to the suction side of the pump, a solenoid valve in the propane line to the torch, and the spark igniters for the torch are interlocked to perform the following functions: (1) Upon closure of the lighting switch the igniters are energized and the propane valve opened, lighting the torch. After a short delay the fuel oil control valve is opened to the burner, and as soon as ignition of the oil fire is established, as indicated by the photo-electric flame detector, the propane torch and igniters are cut off after a short-time delay. (2) Fuel oil is shut off in case of high boiler pressure, high superheat temperature, high temperature at outlet of any furnace circuit, and flame failure. (3) The oil burner is automatically relighted when boiler pressure is restored, superheat temperature restored, or high temperature in any of the furnace circuits is restored to normal. (4) Upon loss of flame, the relighting cycle is repeated several times, and if flame cannot be established, the unit is shut down, requiring manual reset. (5) Upon loss of feed-pump suction pressure or loss of auxiliary set lubricating oil pressure, the oil fire and torch are shut off and the air supplied to the governor of the auxiliary-set turbine is likewise cut off, shutting down the auxiliary set.

Although the designed capacity for continuous running was for 16,000 pounds of steam per hour, the unit ran 40 continuous hours at 21,000 pounds, and was tested up to 22,000 pounds per hour, which was the limit of the blower for continuous operation. Steam temperature leaving the superheater at an output of 16,000 pounds per hour is 870 degrees, rising to 910 degrees at 22,000 pounds per hour, and dropping to 770 at 5000 pounds per hour. Air enters the burner at 450 degrees at a rating of 16,000 pounds per hour, and 500 degrees at 22,000 pounds per hour. Boiler efficiency varied from 75 per cent, based on the high heat value, at a rate of 22,000 pounds per hour, up to 85.5 per cent at a rate of 5000 pounds per hour. Efficiencies were 4 to 5 per cent higher than those originally anticipated.

Starting from cold, the boiler steamed at reduced pressure within 4 minutes and picked up to full load with normal pressure and temperature after 6 minutes more.

FIG. 3.—GENERAL ARRANGEMENT OF EQUIPMENT, DEVELOPMENTAL STEAMOTIVE UNIT.

DISCUSSION.

Dean Potter of Purdue was first to congratulate B. & W., G. E. and Bailey Meter on their cooperative accomplishment. Experiments at Purdue, he said, convinced him that the automatic control will be successful. He wondered why the steam temperature was not carried above 850 degrees and what was done about water treatment. Steamotive, he felt, may have a real future for railway motive power and for space-limited stationary applications.

Several questions were raised by Prof. Christie of Johns Hopkins. How will the control system stand rough riding on the rails? Does scale form on the tubes? If so, how can it be removed? Do the high temperatures threaten sagging of superheater roof coils?

The future of Steamotive for locomotive applications was questioned by E. S. Dennison. Will not a unit working so close to today's limit of compactness, pressure, temperature and control be "touchy"? Has a true economic balance been struck among boiler efficiency, auxiliary power, condenser pressure, etc. (remembering, for example, that a little loss of vacuum will offset a lot of boiler efficiency)? Might not lower steam pressure and temperature be better economics? How much power do auxiliaries take? Why squeeze the steam unit to make space for a costly and energy consuming electric drive when a geared-turbine drive gives full traction and better efficiency at lower first cost?

Comparing Steamotive unfavorably with Diesel, Mr. Dennison said that Diesel oil, delivered, costs only 30 per cent more than "Bunker C" and that actual fuel operating cost of Steamotive will be 93 per cent higher than for a Diesel. He admitted that coal fuel may change this picture.

I. E. Moultrop took the opposite stand, referred to Steamotive as an epoch-making advance whose incidental problems will surely be solved. Experiences at Edgar station had taught him that dire predictions often fail to materialize.

That Steamotive and similar units will have a real future for marine drive was predicted by W. W. Smith. He complimented the designers on a successful 800-R.P.M. reciprocating feed pump.

Several speakers had asked about scaling of the coils. All were therefore interested in the statement of N. C. Artsay that he had operated a straight-tube boiler for two years on sea water. The water (plus a little oil) was sprayed. High velocity carried solids through without deposit.

In his closure, A. R. Smith of G. E. said it is not planned to run Steamotive on raw water. Only condensate and distilled makeup will be used. Operating troubles may be expected at the start, but they will be overcome. The heat liberation of 400,000 B.T.U. per cubic foot is not high. Some day we should easily reach 1,000,000, he predicted. Within two months a unit fired by pulverized coal will start up.

He suggested that the utilities could use Steamotive units to supply steam to industrial plants and sell them their electricity from the transmission lines.

CORROSION OF IRON AND STEEL IN SEA-WATER.

Here, Mr. H. J. Toner, of the Bureau of Engineering, Navy Department, has extracted from the book, "Deterioration of Structures in Sea-water," reviewed in the Book Review section of this issue of the JOURNAL, a resumé of the tests conducted, and results obtained over a period of fifteen years, by a Committee of the British Institution of Civil Engineers, on the action of iron and steel structures in sea-water. While the report corroborates much of the data already known, there are some new slants in the conclusions.

The research committee was guided in the choice of materials by those ordinarily used by engineers in construction work. Its special desire was to ascertain how suitable special steels might reduce the wastage now experienced due to corrosion.

It was found practical by the committee to include in their investigation three representative rolled irons, four ordinary steels, two types of cast iron, and five special steels.

Rolled Irons:—A Low Moor iron was chosen as representative of British manufacture of wrought iron, and a Swedish charcoal iron on account of its special purity. The Swedish charcoal iron gave the following analysis:

Iron	99.82 per cent.
Carbon	0.03 per cent.
Silicon	0.03 per cent.
Sulphur	0.019 per cent.
Phosphorus	0.022 per cent.
Manganese	0.01 to 0.03 per cent.
Copper	0.06 per cent.

This permitted the comparison of a commercial wrought iron with a special high purity iron. Another iron was included, ingot iron, resembling the Swedish iron, except that it had been in a fluid condition during its manufacture. Both the Low Moor iron and the Swedish charcoal iron were produced by the puddling process.

The Ordinary Steels:—The steels used contained the ordinary variations commonly found. The range of carbon covered was from 0.215 to 0.40 per cent; manganese, from 0.34 to 0.85 per cent; sulphur from 0.025 to 0.10 per cent; and phosphorus from 0.027 to 0.067 per cent.

The Special Steels:—Two nickel steels, two copper steels, and a chromium steel of the "stainless" type were included. 0.6 per cent copper was contained in one of the copper steels, while 2 per cent was contained in the other. The nickel steels contained 36 per cent, and 3.75 per cent nickel. The "stainless" steel contained 13.5 per cent chromium.

All the wrought iron and steel specimens, except the stainless steel were in the "as rolled" condition.

The Cast Irons:—Hot-blast and cold-blast cast iron specimens were used.

Low-Carbon Chromium Steels:—Samples of this type containing carbon at 0.15 per cent maximum and chromium at 12 to 14 per cent were used in the "as rolled," annealed, quenched, and tempered condition.

LIST OF MATERIALS TESTED.

Carbon Steels:— A and E: Medium carbon steels, low sulphur and phosphorus.
B: Mild steel with low manganese and high sulphur and phosphorus.
C and F: Mild steel with 0.7 per cent of manganese.
D: Steel with 0.4 per cent of carbon.

Special Steels:— G: Mild steel with 0.6 per cent of copper.
H: Mild steel with 2.2 per cent of copper.
J: Steel with 13.5 per cent of chromium.
K: Steel with 3.75 per cent of nickel.
L: Steel with 36 per cent of nickel.
S: Special soft grade of chromium steel.
T: Special soft grade of chromium steel.
U: Special soft grade of chromium steel.
V: Special soft grade of chromium steel.
W: Special soft grade of chromium steel.
X: Special soft grade of chromium steel.

Irons:— M: Ingot iron.
N: Low Moor iron.
P: Swedish charcoal iron.
Cast Irons:— Q: Hot-blast cast iron.
R: Cold-blast cast iron.

FORM OF SPECIMENS AND CONDITIONS OF EXPOSURE.

I. Plain Bars:—The bar specimens of A and C carbon steels and the wrought irons were cleaned of mill-scale by grinding. These specimens and the special steels, except J, were prepared in the "as rolled" condition. Chromium steel, J, was softened by a low temperature heat treatment. Bar specimens from all samples were prepared for exposure tests for 5, 10, and 15 years. These bars were placed above the level of high water, between the levels of high and low water, and below the level of low water. Complete sets were sent to Auckland, N. Z., Colombo, Halifax, N. S., and Plymouth.

The soft grade chromium steels (S to X) were exposed at Plymouth for 5 years. These bars were treated as follows:

"S:—as rolled, scale not removed.
T:—annealed, scale not removed.
U:—annealed and pickled.
V:—annealed and polished.
W:—quenched and tempered, scale not removed.
X:—quenched, tempered, and polished."

These bars were exposed under aerial, half-tide, and complete immersion conditions.

II. Bars in Combination:—The effects of corrosion on bars when riveted or bolted together, and bars with edges in contact, were examined after five years' exposure at Auckland, N. Z., Colombo, Halifax, N. S., and Plymouth. The following series were used:

"(1) Three sets each of bars E-L, B-Q, and C-N to be placed edge to edge.
"(2) Three sets of bars B and J, with rivets inserted, and of bars D, L, Q, and R, with bolts inserted.
"(3) Six frames riveted together, each consisting of four bars. The combinations were: Two C bars with two P bars, and two J bars with two N bars."

III. Special Tests:—At Plymouth a number of test-bars were prepared for exposure to determine the loss of tensile strength due to corrosion in sea water; the amount of corrosion due to fresh water; and the corrosion of chromium steel in fresh water compared to sea water. Bent bars were exposed to both fresh water and sea water.

"(1) Fourteen tensile test-bars, B, C, E, F, G, H, J, K, L, M, N, P, Q, R, for five years' exposure in sea-water.
"(2) Three sets of bars of all the materials except S to X, for exposure in fresh water for 5, 10 and 15 years.
"(3) Four bars of 13.5 per cent chromium steel, all polished, exposure in aerial and half-tide positions, and for complete immersion in sea-water and in fresh water. These bars were exposed for 5 years. (X-9.)
"(4) (*a*) Twenty-seven bent bars, E, L, M, for exposure in aerial and half-tide positions and for complete immersion in sea-water.
(*b*) Nine bent bars, E, L, M, for complete immersion in fresh water."

CONCLUSIONS.

"1. The maximum differences in resistance to corrosion by the various metals were shown in the aerial and fresh-water tests. In the half-tide, and more particularly in the complete immersion tests in sea-water, the metals behaved more alike.

"2. On the whole there appeared little to choose between the wrought irons and the ordinary carbon steels used in this research in their mean resistance to the various types of corrosion studied. The carbon steels proved superior to the wrought irons in their resistance to aerial corrosion, whilst in fresh water there was nothing to choose. In the half-tide tests the wrought irons were slightly superior and in the complete-immersion tests in sea-water, the wrought irons were decidedly superior to the steels.

"3. Steel high in sulphur and phosphorus but low in manganese (0.22 per cent carbon, 0.10 per cent sulphur, 0.07 per cent phosphorus, 0.34 per cent manganese) proved erratic in its resistance to corrosion.

"4. Increasing the carbon content of ordinary steel from about 0.24 to 0.40 per cent did not appear appreciably to affect the resistance of the metal against corrosion.

"5. The presence of mill-scale accentuated in a marked manner the tendency to localized corrosion and pitting. This was evident under all the conditions of exposure to which the metals were exposed.

"6. The cast irons resisted aerial corrosion exceedingly well, comparing favorably with the best of the alloy steels tested in this research. They also resisted fresh water reasonably well. In the half-tide and complete-immersion tests in sea-water corrosion frequently penetrated to the middle of the bars through pores and casting flaws. The extent of penetration was only ascertainable by fracture of the bars.

"7. The addition of 0.6 and 2.2 per cent of copper to mild carbon steel markedly increased the resistance of the metal to aerial and fresh-water corrosion. This advantage, however, did not appear to be maintained in the half-tide and complete-immersion tests in sea-water.

"8. High-chromium steel of the type containing about 13.6 per cent of chromium satisfactorily resisted atmospheric and fresh-water corrosion. In the half-tide and complete-immersion tests in sea-water the test-bars suffered serious localized corrosion with frequent perforation. This refers to bars tested both with their mill-scale on, and when ground and polished.

"9. The addition of 3.75 per cent nickel to 0.31 per cent carbon enhanced markedly its resistance to aerial and fresh-water corrosion. In the half-tide and complete-immersion tests the nickel steel, however, whilst losing decidedly in weight, manifested a tendency to deeper localized corrosion, which reduced the advantage of the nickel content.

"10. Steel containing 36.6 per cent of nickel proved highly resistant to all forms of corrosion. It was the most resistant of all the materials tested. Steel of this composition also showed comparative freedom from pitting.

"11. Placing dissimilar metals in contact did not lead to any pronounced results in the aerial tests. In all the other tests it was found that:

(*a*) Ordinary mild steel in contact with wrought iron was partially preserved at the expense of the wrought iron.

(*b*) Chromium steel and high nickel steel in contact with ordinary carbon steel were protected from corrosion at the expense of the latter.

"12. Cold working of the bars by bending did not lead generally to any appreciable increase in total corrosion."

THE MOTORIST'S SLIDE RULE.

Senor Arnaldo F. Gomes, Capitao Tenente, —QM—(SB), attached to the Directoria de Engenharia Naval, Ministerio de Marinha, Rio de Janeiro, Brazil, has kindly furnished the JOURNAL with this translation of a pamphlet describing his Slide Rule, which, of course, was originally issued in Portuguese. His idea is covered by Patente de Invencao, n. 23,479 (Com as garantias da convencao de Washington). To any who may be interested in the Rule, and who desire further information concerning it, the author may be addressed direct, and in English.

This slide rule is made up of two parts: One being 40 millimeters wide, by 240 millimeters long, by 8 millimeters thick, while the other, sliding in a double slot in the first, has a width of 20 millimeters. Each slide rule is capable of timing one or more types of engines, the one shown in the illustration being arranged to give the timing for three Diesel engines, as follows:

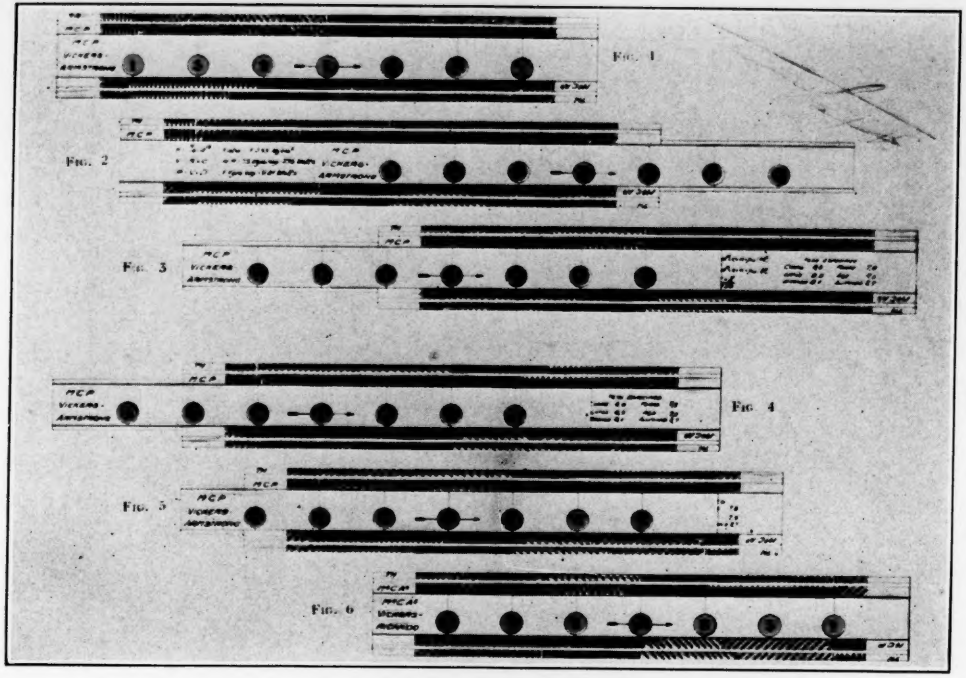
A main engine—six cylinders—1400 horsepower.
An auxiliary engine—six cylinders—240 horsepower.
Two auxiliary engines—three cylinders—120 horsepower each.

The body of the rule is called the "Valve Scale," the blocks next adjacent to the sliding leaf showing the various cycles of engine operation, the outer blocks representing the corresponding theoretical cycles. The four operating cycles of either Diesel or explosion engines of single-stroke type, of course, vary from one engine to another and are shown for a particular engine in the illustration. On the back of the body of the rule (not shown) is the "Standard Diagram," which will hold good for any type of two-stroke engine, because it represents the length corresponding to the rectification of a double circumference, or 720 degrees, *i. e.*, two revolutions of the shaft, or four strokes of the piston. By holding the rule in the position shown in Figure 1, the blocks showing the various cycles of operation of the main engine, marked "M. C. P.," are up, while by holding it in the position shown in Figure 6, those for the auxiliary engines, marked "Ms. C. As.," are up. On the sides of the body of the Rule are placed numbers to represent the degrees of lag, or lead for each stroke, corresponding to the proper timing, while in the upper recessed middle are placed data on measures, and some usual formulae.

The "Piston Scale," or crank scale, is the sliding leaf, and it has on one side, numbers corresponding to pistons, cylinders, and cranks of the main engine, disposed in the firing order of the engine, *i. e.*, 1-2-4-6-5-3-1, while on the reverse it has numbers corresponding similarly to those of the auxiliary engines, with a firing order of 1-5-3-6-2-4-1. The direction for moving the slide is indicated by the arrow. This same scale may be used for readings on the two three-cylinder auxiliary engines, the reading being from right to left, 1-5-3-0-0-0-1, ignoring 6-2-4 as shown. Obviously each of the three-cylinder engines is practically one half of the six-cylinder one.

In the actual rule, the cycle blocking is in colors, but for the purpose of following the single-color illustration, lines as follows have been placed over the colors:

Inlet	Blue	//////////
Compression	Violet	\\\\\\\\\
Combustion	Red	▬▬▬▬▬
Exhaust	Brown	|||||||||



MOTORIST'S SLIDE RULE.

The overlapping of the bands corresponds to the periods when valves cross.

The number of the first cylinder is repeated for sake of clearness. The numbered circles in same colors on the actual rule represent the cranks whose included angle is zero.

Let us take, for instance, cylinders n°1 and n°6. When cylinder n°6 starts the firing stroke just beginning the second turn at 360°, cylinder n°1 is just starting on the first turn at 0°, on the inlet phase. Thus it is obvious that n°6 crank precedes n°1 by just 360°. The same thing occurs with cranks n°2 and 5, and 3 and 4.

Timing of valves.

The valves are timed according to the makers of the engines as follows:

M. C. P. (Main Engine).

Inlet opens	at 0° or U.D.C.	closes at 25° A.L.D.C.
Compression	at 25° A.L.D.C.	at 8° B.U.D.C.
Firing	at 8° B.U.D.C.	at 52° B.L.D.C.
Exhaust	at 52° B.L.D.C.	at 12° 5 A.U.D.C.

Note.

U.D.C.—Upper dead center.
L.D.C.—Lower dead center.
A.—After.
B.—Before.

The injection period:—8° B.U.D.C. to 27° A.U.D.C. is not shown on the rule.

Ms. C. As. (Auxiliary Combustion Engines).

Inlet opens	at 14° B.U.D.C.	closes at 27° A.U.D.C.
Compression	at 27° A.L.D.C.	at 18° B.U.D.C.
Firing	at 18° B.U.D.C.	at 53° B.L.D.C.
Exhaust	at 53° B.L.D.C.	at 15° A.U.D.C.

The injection period is not shown on the rule.

The overlapping period is: 12°,30′ for the M.C.P. (Main Engine); 29° for the Ms. C. As. (Auxiliary Engines).

The timing for reverse is the same, only that the cylinder numbers are read from left to right on the piston scale. This must be done after the reversing gear has been put in action, changing the cams on the camshaft.

HOW TO USE THE SLIDE RULE.

1—It is interesting to all those who study Diesel or petrol engines, to know what is going on in any cylinder, while the one under observation is, let us say, on the start of the firing stroke, if it is either a Diesel or a petrol engine.

This study is made much easier with this slide rule, than with the usual graphical diagrams.

The said diagrams must always have two concentric circles, whence results a certain confusion between inlet and combustion, and also between compression and exhaust.

2—When any crank is placed under any one of the double-colored strips, this indicates crossing of valves, the rule will show which cylinder is starting to fire.

That means that either the injection pump corresponding to that particular cylinder is just starting its injection period, in the case of a Diesel, or the sparking plug is just flashing, in the case of a petrol or explosion engine.

Reciprocally, if we set the rule to show which cylinder is starting combustion or explosion, we can see at once which one is on the inlet period and what operations are occurring in the other cylinders.

3—It is sometimes very difficult to observe the marks on the flywheel on account of being so small or of difficult visibility due to weather action or corrosion. On the flywheel there is a mark stamped, corresponding to the exact moment in which the cranks are at U.D.C. (upper dead center), but this mark also shows the starting of the exhaust and the end of compression periods. On the other hand, the camshaft has one half the number of revolutions of the crankshaft.

The usual method of distinguishing one from the other is by removing the spark plug, in order that a flow of air may show that compression is taking place.

4—The most usual use of the rule is for petrol or explosion engines, because of the facility with which magnetos are removed and ignition cables are disconnected from spark-plugs, for repairs or replacement. When timing a petrol or explosion engine, the cylinder head cover is removed so that the valves may be easily seen.

The use of the rule then is very simple, and the best method is to start from the cylinders that have both valves open.

Timing of a petrol engine may be accomplished as follows:

(*a*)—The first step is to establish the firing order, if unknown. By carefully watching the succession of inlet valves, exhaust valves or crossing period in all cylinders, one after another, the firing order may be easily determined, provided the shaft is running in the right direction.

(*b*)—If the corresponding number of any crank is brought to the double-colored strip which indicates the crossing, the rule will show which cylinder must receive its corresponding ignition cable, from the magneto or distributor.

(*c*)—After this is done, the terminals of the cables should be marked with the number of the corresponding cylinder.

(*d*)—The cylinder head cover should then be replaced, ignition cables connected to the spark-plugs, and the motor will be ready to start working. These operations should always be performed starting from n°1 piston or crank, following the firing order, as shown on the rule.

The use of the rule avoids markings on the flywheel or removing spark-plugs.

Each type of engine may be equipped with a rule according to its design, as part of the tool equipment furnished by the makers.

5—Slide rules are also obtainable for 1-2-3-4-5-6-8-10-12 and 16 cylinder engines, either in line or V type. They may be used for any type of four stroke single effect engines, installed on cars, trucks, boats, aircraft, stationary or railroad plants. The slide rule provides means for speeding up work, avoiding wrong connections of spark-plugs, connecting cables and etc., especially on certain complicated engines as those with a large number of cylinders and equipped with dual ignition.

6—It is known, that, by dividing 360° by the number of cylinders, we obtain the crank angles, in engines of three or less cylinders. This is the case of the Ms. C. As. (auxiliary engines). In a case of four or more cylinders, the dividend will be 720°, because the cranks are disposed in groups of two, at 0° angle. This is the case of the M.C.P. (main engine).

7—It does not matter whether the cylinders are in line or in V, the rule will show the crank angles; as each pair of opposite pistons is connected to the same crank.

The rule shows the numbers in a single row, for engines with cylinders in line, and in a double row for V type engines.

The crank angle on V type engines is determined by the intersection of the opposite cylinder center lines, when the connecting rods are attached to the same crank.

The number of crank throws for V type engines, are:

4 for the 8 cylinder
6 for the 12 cylinder
8 for the 16 cylinder

The opposite cylinder axis angles are respectively 90°, 60°, and 45°. Cranks are within the piston scale, whatever number of cylinders the engine may have.

8—From what has been said, we may conclude that:

If we subtract the number of the cylinder that is on the end of exhaust period and starting on the inlet period (crossing of valves), from the total number of circles (equal to number of cylinders plus one, because n°1 cylinder is repeated) we have the number of the cylinder that is just starting the firing stroke.

The above is the general rule, for four or more cylinders in line engines, and is applicable to V type engines of eight, twelve and sixteen cylinders; if we consider the numbering for the eight cylinder engines as follows:

RIGHT	AND	LEFT
1-2-3-4		1-2-3-4
for the twelve cylinder engines:		
1-2-3-4-5-6		1-2-3-4-5-6
for the sixteen cylinder engines:		
1-2-3-4-5-6-7-8		1-2-3-4-5-6-7-8

Exceptions to this rule are those engines of which two cylinders of the same side, fire one after another, such as the Ford V8 and the Cadillac V8.

The above numbers should be placed on the rule in the firing order of the cylinders.

9—We have Slide Rules for the various types of two-stroke single effect engines, also, for the four-stroke and radial engines in service in our Navy.

We have also some rules for four- and two-stroke double effect engines.

10—For sake of better explanation, we give below several examples relating to Main Combustion Engines, on the present model of rule obeying the terms of the Rule (principle).

I—The rule as illustrated (figures 1 and 6) shows the crank of n°1 cylinder by the double strip (overlapping) and shows the cylinder n°6 (7–1) starting to fire.

We observe this coincidence on the right crossing as well as on the left.

Besides these crossings correspond to one same position, *i. e.* the initial and final point of a double rectified circumference.

II—If the crank of n°6 cylinder is overlapping (figures 2 and 3) it is indifferent to use either side of the rule, as n°1 (7–6) cylinder presents itself ready to receive the spark or injection in either of the positions (to right or to left).

III—As to the cylinders following n°6, they require the use of the overlapping strips to the left. Thus, if crank n°5 is on the left overlapping (figure 4) the rule shows cylinder n°2 (7–5), to which shall be connected the ignition cable at the moment of the flash of the spark or the start of the squirt of injection, in the case of a Diesel engine.

The same happens with cylinder n°5 (figure 5) and the rule shows that cylinder n°4 (7–3 is ready to receive the spark or the injection.

According to the above examples presented we can establish that the Rule is applied from the right overlapping, for the first half to fire (1–2–4), and from the left overlapping for the second half to fire (6–5–3).

After having considered the cases of the main engines (M.C.P.), we will take the auxiliary engine (M.C.A.).

We will take the Rule, turn it through an arc of 180°, take out the "Piston Scale," turn it completely over, slip it back in its slots, and we have the Rule ready for the study of the auxiliary engines.

We shall for this case repeat the above examples presented, though taking in account the difference of numbers, for as it happens, the firing order is not the same (fig. 6), we have, therefore, the Rule confirmed. In the case of the auxiliary combustion engine (M.C.A.), the first half is composed by cylinders 1–5–3, and the second half by cylinders n°6–2–4.

Our object is to help our future officers with this small help, so that they may fully understand the operation and management of the Diesel engines on our training ship *Almirante Saldanha,* on her next voyage; especially in what many regard as being a great secret: TIMING THE ENGINE.

DEVELOPMENTS IN PLASTICS.

This editorial taken from Engineering, London, England, and published in the November 27, 1936, issue, will be of interest to all who have read Mr. Cassey's article on the Phenol Resinoids appearing in this number of the JOURNAL. It indicates very clearly the wide interest in resinoid development which is being felt both here and abroad.

The striking manner in which the plastic industry has established itself among us is illustrated by the fact that whereas formerly this country had to import the plant needed, we are now, on the other hand, considerable exporters of the machinery used for working up this product. In addition to the requirements due to the natural development of the industry, the speed with which changes have been introduced has been such that plant has quickly become obsolete and in need of prompt replacement by other machinery of an entirely different character. The versatility of engineers engaged on this work, however, has enabled plastics manufacturers not only to expand their factories, but to decrease to a considerable extent the amount of unemployment.

The recent development of the application of this material to aeroplane propellers and construction may be regarded, perhaps, at the moment, as the most daring use to which it has so far been put. There are, however, numerous others already established, almost equally interesting. Laminated resin products made by British firms are proving their worth, for instance, for heavy bearings, while in chemical works and factories in which corrosive vapors or liquids have to be handled they have found many special fields. For example, a fan of the material will handle without injury corrosive vapors such as hydrochloric-acid gas, even at a temperature of 100 degrees C. In a recent test one such fan delivered 1600 cubic feet of this gas per minute at 17 inches w.g., when operating at 2300 R.P.M. under such conditions. In the matter of piping the material is likewise creating a field for itself, and the following figures give some idea of what it is capable of withstanding. A flanged pipe 2 inches I.D. and 2.43 inches O.D., subjected to a hydraulic test at 225 pounds per square inch pressure, showed only slight leakage at the flange threads at the ends; it was not until the pressure reached 1300 pounds

per square inch that leakage appeared at a few pin holes along the pipe. As this piping was intended to be used at pressures of only 50 pounds per square inch, the margin was obviously ample.

As auxiliary materials in the engineering industry the field of plastics is constantly widening. One such field, and that a not unimportant one, is in the varnish and lacquer industries. In the past few years quite a new manufacturing technique has been developed in these trades, with an accompanying reduction in the cost of raw materials, a simplification of the compounding processes, and an improvement in the finished products. This is due, to a large extent, to the fact that good-quality synthetic resins of uniform composition are now available, while the other half of the varnish—the solvent—has been considerably reduced in cost by the introduction of new hydrogenated solvents from coal. These solvents include hexaline from the hydrogenation of phenol; methyl hexaline from cresol; and tetraline and decaline obtained by hydrogenating naphthalene. All these have great dissolving power for synthetic resins. Coumarone resin varnishes are now made in three distinct types, viz., spirit, oil, and chemically-resistant. Spirit varnish is prepared by simply dissolving the coumarone resin in tetraline or other solvent. The making of oil varnish is simplified by first dissolving the resin in one of the hydrogenated solvents before introducing oil and driers. Due to its resistant properties, coumarone resin is being applied as a coating for ships' bottoms and other structures in contact with sea water. Both coumarone resin and resins of the bakelite type are employed for coating storage tanks and other containers, specifically for the storage of coal-tar derivatives, petrol containing tetra-ethyl lead, and other petroleum products. Small containers, such as barrels and cans, are often lined internally with a coating of synthetic-resin varnish.

In the manufacture of lacquers, artificial resins are now taking the place of nitro-cellulose to a limited extent; this permits the use of a wider range of solvents. The modern cheap lacquers frequently contain bakelite resins in addition to nitro-cellulose. As plasticisers in lacquers, artificial resins are now regarded as one of the most important ingredients; it is not often that a good lacquer is made without some form of plasticiser, the durability of the lacquer film being dependent upon this substance. Both urea-formaldehyde and coumarone resins are steadily gaining in popularity as plasticisers for some grades of lacquers, although in other types the older materials, like ester gum and dibutyl phthalate, are still preferred.

British manufacturers have, of late, taken up the production of urea—one of the raw materials for urea-formaldehyde resins—and their factories are now turning out enough to supply all demands of the home market. A considerable fall in price has resulted and this, in turn, has enabled the laboratory processes for making urea resins to be carried out on a commercial scale. Resins of this class, besides finding application in varnish making, are coming into favor in other directions not usually associated with the plastics industry. For example, the fusible resins are marketed in the form of solutions in water, and are employed in the building trade as a priming coat for plaster and for wood surfaces, and also in the textile industries for waterproofing fabrics and for the preparation of size. The electrical industry also makes use of them, particularly of those produced with an acid catalytic agent, these having, it is said, the greatest insulating value. Besides the coating of paper and fabric insulation with urea resin varnish, the resin itself is used as a binder for finely-divided iron in the manufacture of certain magnet cores.

Perhaps the most interesting outcome of work on urea resins is the new so-called "organic glass," which is a special type of the resin, unfilled, but

rendered infusible by heat as in molding. This substance is superior to glass in some respects, but inferior in others. It weighs only about half as much, which renders it advantageous for aircraft, and it is not splintered by a bullet or shell fragment, but its transparency, while equal, in the new condition, to that of glass, is liable to suffer with use, as its surface, being softer, is easily scratched and disfigured. Strong chemicals, like acids, to which glass is generally inert, also gradually attack it. Organic glass is readily machinable and may be treated in the workshop exactly as is done with laminated or bakelite moldings. Its tensile strength approaches 4 tons per square inch, whilst the compression resistance is about 14 tons per square inch. The preparation of this material naturally demands extreme care. Iron is its greatest enemy, and the raw materials used must be iron-free, while manufacture must proceed in non-ferrous vessels. In the process, the resin is molded and hardened at relatively low temperatures, usually not over 100 degrees C. Other types of artificial resin, at present cheaper than urea resins, are being tried out as organic glass. These are produced primarily as thermo-plastic powders, which may be moulded either by compression or by injection. The density of the material so made is about 1.2, being somewhat lighter than bakelite. Its physical and mechanical properties compare favorably with metals, timber and other materials of construction, while it has a very low thermal conductivity and is a good electrical insulator. The building trade is experimenting with this material for the production of parts of walls in buildings in which windows of the usual form would not be employed. Instead, transparent bricks would be built in in certain areas without any break in the surface line of the wall.

In an entirely different sphere plastics are being applied as factory roofing material. Roofing in large industrial centers is apt to suffer rapid deterioration from the effect of atmospheric acids, gases, and fumes, &c. A new roofing substance, which is finished in the form of corrugated sheets, comprises an imperishable compound of asbestos with an asphalt and resin binder consolidated by high pressure, and having a steel core, which is permanently sealed from any external corrosive influence, no paint or other protective coating being necessary.

To reduce the costs of raw materials for plastics manufacture, the soya bean, among other materials, is being pressed into service, and in view of the large-scale growing tests now being made with the bean in Great Britain, the possibilities of an established soya-bean plastics industry in this country are more favorable than hitherto. As yet the development of plastics from the bean has been in the hands of one of the big motor-car companies. The oil of the bean is first extracted for use as an important ingredient of the baking enamels employed as body finishes on cars, and as a core binder in the foundry. The meal remaining contains nearly 50 per cent of protein matter; this is treated with formaldehyde to produce a synthetic resin, which can be filled and molded to produce small parts, such as gear-shift lever balls, lighting switches and ignition-distributor covers.

Synthetic rubber is no longer merely a fantasy, and at the present time several types are manufactured. A representative of this new material is made from chloroprene, hydroquinone and methyl alcohol. This gives a plastic substance simulating the physical properties of natural rubber very closely. In one respect it may be considered to be even better, since it may readily be vulcanized without such aids as sulphur. This synthetic material may be used in much the same way as synthetic resins are used. For example, in the molding industry the usual fillers and pigments may be added and the product molded to give a large variety of goods having satisfactory mechanical strength and chemical resistance. Synthetic rubber lends itself admirably to sheeting processes on the calenders, and also to die-extrusion to give string-

like rods. Its properties may be modified by the addition of other materials; glue makes it more oil-resistant than rubber, while toughness in the vulcanized product is obtained with certain oxides of metals. The finished article may have the soft elasticity of a rubber band, or the hardness and durability of a solid tire, depending on the ingredients incorporated when vulcanizing. Natural rubber-latex is a modern material which is now applied in many directions, chiefly for spreading, electrical deposition, and for spraying processes in which rubber is a required ingredient. Its synthetic counterpart has already appeared. This synthetic latex may be made from chloroprene by emulsifying the liquid in a solution of soap. In the synthetic latex the particles of rubber deposited are completely vulcanized, but with the natural rubber latex this is by no means always the case. Claims are made that the synthetic rubber has definite advantages, notable among these being the high resistance to both mineral and vegetable oils, and to oxidation. Heat, which softens rubber, serves only to harden artificial rubber. Synthetic rubber latex is also much less permeable to gases and for this reason is being adopted in airship construction for the gas bags. While on this subject, reference may be made to one serious disadvantage of rubber for certain work, namely, its inflammability, which is of great concern in cable manufacture. With the object of lessening the fire risk with cables, one company has placed on the market a new series of plastic materials in the form of synthetic waxes, made by the chlorination of naphthalene, and produced in a number of grades with specific melting points. When incorporated with the rubber component of the cable, these waxes reduce the fire hazard to a minimum. They may also be used as substitutes for bitumen in the protective coverings on the exterior of electric cables, and in the making of non-inflammable floor tiles. The advantages of such flooring in ships and in multi-storied buildings will be obvious.

PROGRESS IN LINER WEAR REDUCTION—THE LISTARD PROCESS.

This matter is becoming increasingly important, as more and more Diesel engines are being produced in this country. In this country, we are attacking the problem of liner wear by improved methods of securing the liner, by the use of higher Brinnell types of cast iron, and by coating steel liners with a cast iron lining. The British Listard method is a chrome-hardening process after chomium has been deposited electrolytically on the cast iron. The article is extracted from The Marine Engineer, London, England, the issue dated November, 1936.

Ever since the marine Diesel engine became popular for ship propulsion, the subject of cylinder liner wear has exercised the minds of designers and superintendent engineers. Metallurgical progress, improvements in piston ring design and material, close attention to lubrication and liner cooling, and other factors have also contributed towards better conditions as regards liner and ring durability. At the same time, no engine builder would suggest that the last word has been spoken on the subject. Nitrogen-hardened liners, for instance, represent a distinct advance and other commercially-successful contributions to the problem could be cited were space available. The purpose of the present article, however, is to bring to the notice of our readers the latest—and certainly one of the most interesting—development in connection with the combating of liner wear. We refer to the Listard process of chromium hardening, recently introduced by R. A. Lister & Co., Ltd., and demonstrated to an interested party of engineers at the London office of the firm.

The process is the result of eighteen months' research and experiment at Dursley, where a special laboratory and workshop were built to enable the experiments to be carried out in secret, without interfering with the normal running of the factory. The new process, which has been registered under the name of Listard (Lister-hard), reduces cylinder or liner wear to a minimum.

In view of the importance of the invention to the engineering industry, Lister's have decided to make available the results of their experience to any British Diesel engine manufacturer taking up a license to use the process. Although the process will be used only in Diesel engines, the principles on which it is made apply equally to motor car engines, aeroplane engines, tools, and other classes of machinery where the increase of wear resistance affects the efficiency of the product. It may have far-reaching effects in the development of the Diesel motor car and the Diesel aeroplane, if the promise held out by the experience already obtained with the process is realized.

Listard is based on a Dutch invention brought to Lister's in February, 1935; in March of that year experiments were put in hand on cylinders chrome-hardened according to this process. Realizing from the beginning the importance of the invention if it could be applied commercially, Lister's decided on the erection of a special plant and laboratory in which to make their own independent investigations and experiments. These were constructed while the original experiments were being carried out. The plant and laboratory were ready in August, 1935, and since then tests and experiments have been continued. The result is Listard, on the development of which over £50,000 has already been spent.

Listard is, briefly, a chrome-hardening process. By electro-chemical means a deposit of chrome is deposited on cast iron. This gives a surface harder than anything of the kind yet known, a surface which is said to resist both chemical and mechanical wear to a greater extent than ever before. The final Listard process is the result of successive experiments carried out at Dursley. The first problem was to find a satisfactory basis metal to give results. This led to the rejection of cylinders of hardened cast iron and cast iron in which hydrogen was present. Experiments were then made to determine the effect of the Listard process on oil consumption and general efficiency, and to see how far existing lubrication methods had to be adjusted. Next, tests were made to find out the most suitable class of finish for the cylinders—grinding, honing or lapping—after they had been processed. Simultaneously with these tests, the cylinders were subjected to continual modifications to obtain the result desired.

As a result of trial and error, the tests ultimately gave the correct method of making the deposit, the best surface to finish in, and the best method of obtaining the finished surface. This surface, for cylinder purposes, has, its sponsors are satisfied, the longest wearing surface yet discovered—the surface, that is, which gives the greatest efficiency over the longest period.

The tests to which Listard has been put at Dursley indicate that not even the hardest cast iron cylinders will stand up to the effects of wear, whether it is due to heat, chemical action, or abrasive wear from the piston rings, as effectively as cylinders treated with the Listard process. The hardness of a cylinder is usually described in terms of degrees Brinell. This method is not effective where one metal is built on to the surface of another, as the soft metal underneath gives way to the pressure. A better method of testing its hardness is by scratching the surface under a given pressure with a hard object, such as a diamond, and measuring the depth of the scratch.

These are the results of actual experiments carried out a Dursley:—

Diameter of cylinder 4½ inches, speed 1000 R.P.M. One Listard-processed cylinder and one nitrogen-hardened cylinder were run side by side in the same engine, cold by day and hot by night, the combustion pressures being higher

than normal. The total running hours were 1500, and the following results were obtained:—

Wear on the nitrogen-hardened cylinder—4½ thousandths of an inch.
Wear on the Listard cylinder—1½ thousandths of an inch.
This gives a wear resistance in favor of the Listard cylinder of 300 per cent.

The second experiment was as follows:—

Diameter 4½ inches, speed 1000 R.P.M. One Listard-processed cylinder and one nitrogen-hardened cylinder were used. The running conditions were similar to those in the first test and the total running hours were 3200. The results were:—

Wear on nitrogen-hardened cylinder 7 thousandths of an inch.
Wear on Listard-processed cylinder 2½ thousandths of an inch.
This gives a wear resistance in favor of the Listard cylinder of 310 per cent.

A third test, even more drastic than the foregoing, might be referred to because the engine lubricating oil *had been diluted with 50 per cent of fuel oil* before commencing the trial. The cylinder tested was of 4½ inches diameter, the speed was 650 R.P.M., and the running conditions were as above. The total running hours were 3000 and the results were:—

Wear on nitrogen-hardened cylinder 12 thousandths of an inch.
Wear on Listard-processed cylinder 1½ thousandths of an inch.

This gives a wear resistance in favor of the Listard cylinder of no less than 800 per cent.

A large number of Listard cylinders are now under practical test in many parts of the country. These are being periodically inspected, and all show excellent results. Others are on test in foreign countries, and in not a single instance has any failure been reported.

THE MICRO-GAP SWITCH

This discussion of a paper delivered before the British Institution of Electrical Engineers by Professor W. M. Thornton, on December 17, 1936, appeared in The Engineer, London, England, December 18, 1936. It describes an A.C. switch capable of breaking a 250-volt, non-inductive circuit with a contact separation of about .005 inches. In modern alternating current applications it has possibilities of reducing both weight and space requirements.

In a paper by Professor W. M. Thornton, read before the Institution of Electrical Engineers on Thursday, December 17th, an A.C. switch capable of breaking non-inductive circuits with an extremely small separation of the sparking contacts is described. On a 250-volt circuit the separation is in the neighborhood of five-thousandths of an inch. It is shown that the current is interrupted not by stretching the arc at the break, but by the mutual repulsion of electrons that leave the contacts and enter the gap. The switch is most suitable for the thermostatic control of electric heating systems. Oscillograms indicate that when the contacts in those switches begin to open at any point in a half wave, the current breaks at the next zero point and does not restrike. If broken at zero it persists for the next half wave.

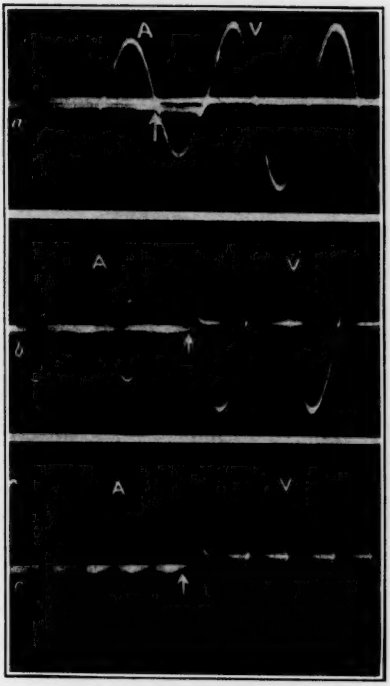
The perfect switch for a normal A.C. circuit is that which, when it opens the circuit at any point in the half-cycle, prevents the restoration of the arc after the current has fallen to zero. The restriking of the arc depends on two things, the voltage across the gap and the conducting state of the medium in it. In large power circuits the former depends greatly on the frequency

and amplitude of the oscillations set up across the break. In non-inductive circuits these are negligible, and the only field across the gap is that of the circuit voltage. Whether this is sufficient to cause the arc to re-form depends on the length and conductivity of the gap; that is, on the state of ionization of the air or oil vapor or of carbonization of the oil itself. The ionization of an air switch gap is caused by the injection into it of electrons from heated contacts, and by collision of these with molecules under a high voltage gradient. The emission of electrons at low gradients is solely thermal in origin; it depends only on the temperature of the contacts. If a break greater than the free sparking distance were formed instantly in a non-inductive current-carrying circuit, there would be no arc, for the contacts would not have time to get hot, no electrons would be emitted, and the arc or break spark could not form. There have been many devices to keep the contacts cool at break. These have been mostly concerned with large power circuits, but for relatively small powers and circuits that are, in effect, non-inductive, a form of switch is available that is, according to the above definition, perfect in action.

The thermostatic control of the temperature of electrically heated water has been made much easier by the invention of the micro-gap switch. Satchwell's arrangement marked a new departure in the automatic control of low or medium-voltage alternating-current circuits, in particular when they are as nearly as possible non-inductive. The circuits to be broken are in most cases those of the heaters controlling the hot water or air supply for buildings, in which the temperature has to be kept constant within a few degrees. To do this the switch is operated by a bimetallic device, which consists, in the hot-water thermostat, of a non-expanding rod contained within an expanding sleeve. The difference in the lengths is extremely small, about 0.00011 inches for a 12-inch length per degree F. The switch tongue on which the expanding element presses is held by a small permanent magnet until the force upon it overcomes the magnetic pull, and the gap opens suddenly. The length of gap is adjusted by a back stop so spaced that the current, after passing through zero, cannot restrike. The contacts are flat, ¼-inch to ⅜-inch diameter, and are made of silver, not only because of its high thermal and electrical conductivity, but because the oxide of silver, if it should be formed by the arc, is electrically a good conductor. On a 250-volt circuit the opening of the gap is about 0.005 inch. When the contacts separate the current may have any value from zero to the maximum. Oscillograph records of the current at break show that, at whatever point in the cycle the contacts open, the current stops at the next zero point. This is sufficient evidence of the perfect action of the micro-gap switch.

Any air gap, however small and highly ionized, has a resistance greater than that of the metal of the contacts. Since these are not perfectly smooth, the final separation is at one or more points on the surface. There is a local concentration of current, the density rises, and the metal heats to a temperature depending on the total current broken. From these hot points electrons can leave the metal, and enter the gap, but they do so gently. Their motion within and just outside the metal is according to the Maxwellian law of distribution of energy of particles in collision. This is the first stage in any break of circuit. Once the electrons are free in the gap they are acted on by the field across it and accelerated. The kinetic energy they then acquire is proportional to the product of the field and the gap length. By keeping the latter very small, the energy of the electrons in line with the field is diminished, and since the pitting of the contacts is due to the energy of bombardment by the current stream, it also is greatly lessened.

If there were no voltage gradient in the gap, any electrons in it would repel one another and be expelled sideways as if there were a miniature



Oscillograms Showing Relations of Current and Voltage.

explosion. This can, in fact, be seen to occur. It is the special and characteristic feature of micro-gap breaks that the current is always broken only by a lateral spread of the arc through mutual repulsion of its elements, not by stretching the arc.

When there is no back stop and the arc lengthens, as far as the voltage of the circuit can maintain it, other physical actions come into play. The lateral spread may be checked by the attraction of the current elements forming the arc, and the current itself is reduced by the influence of its increasing resistance in the circuit. The arc that breaks is pear-shaped, with the blunt end at the cathode. The attraction between electrons moving in the same direction only balances their mutual electrostatic repulsion when their velocity is equal to that of light, so that the pear-shaped long arc depends more on attenuation than on "pinch" effect.

The electric strength of air between parallel surfaces is such that an A.C. voltage of 250 R.M.S., or 350 maximum, will not break down a gap of 0.005 inch. For a 500-volt circuit 0.01 inch is required. These define the gap lengths that may be used. Even with the latter relatively large gap a circuit carrying 100 Kw. has been interrupted without the arc restriking or the contacts pitting. How far it may be possible to apply the lateral repulsion action to high-voltage circuits remains to be seen.

The advantage of this type of switch would appear to be confined to low-voltage non-inductive A.C. circuits, and where, as in the case of thermostats, the operating movement is small.

The oscillograms reproduced show the relations of current and voltage in the gap in three typical cases—(*a*) when the circuit opens as the current passes through zero, but does not break until the next zero; (*b*) when the circuit opens at 45 degrees before zero, the current breaking at zero; (*c*) the circuit opening when the current is a maximum, the current breaking at zero. The voltage in each case was 250 volts, and the current 15 amperes. The time scale is in each case from left to right. The arrow indicates the point where the switch opens.

In (*a*) the small voltage across the gap is nearly uniform during the half-period, rising slightly, and reversing to a full maximum, when the current stops. The change from the current curve to the voltage curve is shown only by the increase of amplitude after the break. In (*b*) the voltage begins to rise at the moment the circuit opens, about half-way between the maximum and zero, but reverses as the current reaches zero. In (*c*) the point where the rise of voltage begins is mid-way between the zero points, *i. e.*, at the maximum value of the current.

These oscillograms show that the best place to break a non-inductive circuit is not at zero current, but in the quarter-period before a zero point. There must be some electrons in the gap to repel one another and to break the circuit.

It is possible to break nearly non-inductive currents, such as those in radiators, without a destructive arc, even when the motion is slow, as by withdrawing a plug from a socket; but when a parallel gap is set to non-striking distances, though not lengthened indefinitely, the breaking action is by a lateral repulsion of the electrons in it, and not by stretching the arc.

An interesting point was observed by Mr. R. Bruce, who took the oscillograms. In most cases the gap began to open at the moment the current reached a maximum value, always of the same polarity. This suggested that there might be, in addition to the thermal expansion, an electromagnetic action causing the gap to open. Mr. Bruce found, then, that the switch when delicately set would operate with large currents without any expansion of the thermostat elements. On inquiry it was found that this effect had been observed before, though not explained. It is clearly due to a resultant weakening of the magnetic hold of the permanent magnet on the soft iron armature.

The magnetic field of the current flowing through the contacts over the permanent magnet to the terminals deflects the field away from the poles and weakens the resultant pull. A switch of this type therefore breaks automatically on overload and is an additional safety device in the circuit.

THE PETTER HARMONIC INDUCTION ENGINE.

While the idea of harmonic induction in a Diesel engine is not new, it is believed that the engine described in this article extracted from the Shipbuilding and Shipping Record, London, England, December 17, 1936, is the first to be built which successfully employs the principle. By taking advantage of the wave motion established in the exhaust by the ejection of the products of combustion, it is possible to eliminate from the engine all usual external methods of accomplishing the scavenging.

As a result of experiments carried out over a number of years, Petters Limited, Yeovil, have recently constructed a two-stroke Diesel engine which makes use of the principle of harmonic induction. Last week a demonstration was held at Burwood House, Westminster, where single-, twin- and four-cylinder models were shown.

The intended interpretation of the word "induction" is that the fresh air which is required to recharge the cylinder before each stroke of the engine instead of being pumped into the cylinder as in the case of a normal four- or two-stroke engine, is drawn or sucked in by means of a vacuum which is produced as a result of the wave motion in the exhaust pipe.

When the exhaust valve in the engine opens, the sudden ejection of the burnt products of combustion from the cylinder into the exhaust pipe sets up a wave motion in this pipe. This motion is similar to the motion of the waves produced in an organ pipe, the initial compression wave being formed by this sudden ejection into the exhaust pipe. Immediately following this compression part of the wave, there is a vacuum or rarefaction part which completes the wave cycle. This rarefaction is transmitted from the exhaust pipe through the exhaust port into the cylinder, and at exactly the right moment the ports in the cylinder connected to the atmosphere are opened, thus connecting the vacuum in the cylinder to the pressure in the atmosphere, the result of this being that the clean air rushes in from the atmosphere and fills the cylinder completely, thus the cycle of operations in the cylinder may be repeated.

As is well known, in the design of organ pipes, the frequency of the waves in the exhaust pipe, *i. e.*, the number of waves per second, is governed by two factors; they are the length of the pipe and the speed of sound in the medium in the pipe. As the latter of these is fixed by contingencies which are not under the control of the engine designer, it is important that the right length of pipe is used in order that the waves in this pipe are timed correctly, so that they coincide with the opening of the exhaust valve and the opening of the air ports, *i. e.*, at the moment that the air ports of the engine open, it is necessary to have the vacuum in the cylinder; therefore, it will be seen that for any particular speed of operation of the engine there is a definite length of exhaust pipe required. Fortunately, once the length of exhaust pipe has been fixed, the speed of operation of the engine is not absolutely rigid, and a certain amount of flexibility is obtainable. The result of this method of filling the engine cylinder with fresh air at each stroke of the piston is that it is possible to do away with all the usual methods of refilling an engine cylinder with air, *i. e.*, the idle strokes of a four-stroke cycle or the auxiliary compressor of a two-stroke cycle engine.

The exhaust valve is situated in the cylinder head operated from the camshaft, which is gear-driven from the main crankshaft. The fuel injection nozzle has a single hole, centrally placed, which is of relatively large diameter, and therefore remarkably free from the danger of being choked by carbon deposit. Since the wave motion in the pipe only functions above a certain speed of the engine, there is an auxiliary device whereby air is supplied from the crankcase for starting, but once the engine has run up to speed, the automatic scavenge system operates of its own accord.

The advantage of the method of scavenging adopted is that not only are all exterior methods of supplying air to the engine removed, but more complete scavenging of the engine is effected than is usually obtainable in a two-stroke unit, so that approximately 50 per cent more power is developed per cylinder volume than in a standard two-stroke engine. This has the effect of lowering the power weight ratio of the unit.

LIGHTWEIGHT BOILERS FOR HIGH-SPEED SHIPS.

This article, "Ueber leichte Kessel fuer schnelle Schiffe," by Friedrich Muenzinger, VDI, appeared in Schiffbau, Berlin, Germany, issue of February 15, 1936. Although Doctor Muenzinger has twice lectured on the same general subject in England since this article was published, it appears to possess the fundamentals of the idea he has since striven to bring home to shipbuilders. It furnishes a sound basis for any discussion of the marine steam plant of the future.

I. INTRODUCTION.

The safety of operation and simplicity of steam power and the superiority of the rotary motion of turbines over the reciprocating motion of the driving gear of internal combustion engines, in conjunction with the great progress in the technical improvement in steam drive since the end of the war, especially for high-speed ships, have given a new impetus to the development of steam.

High-grade gear made it possible to exploit one of the principal advantages of steam turbines: high speed, and to build marine turbines up to the highest power as easily and economically as stationary machinery. But, as was the case in power station design, the development of marine boilers did not keep pace, mainly because the possibilities of oil as compared to solid fuel in boiler construction were only gradually recognized and utilized. In adopting light boilers designed for high pressures and high temperatures, and other improvements in ship construction, the application of high furnace loads and forced circulation are two important steps in a promising development, which will be characterized by constant improvement in the mutual adaptation of boiler and furnace and within which very high furnace loads are destined to play a role similar to that of high speeds in the case of turbines.

If in the following, some conclusions are intimated rather than expressed, this is done, among other reasons, because the success of a specific "system" depends not only on its "absolute" advantages and disadvantages, but also on the amount of good judgment, constructive ability, money, etc., expended on its development. Therefore, failures, which obviously are due more to accident than to real flaws in a type of construction, should not be taken too seriously, even if in one or the other case they may perhaps have caused much annoyance.

II. CHARACTERISTICS AND ADVANTAGES OF FORCED CIRCULATION BOILERS.

(*a*) *General.* Since about 1930 forced circulation boilers have been very successfully applied to ship construction. They have the following advantages as compared to natural circulation boilers:

1. convenient lining of the furnace with heating surface;
2. boiler shells unaffected by sudden temperature changes and pressure variations, and easily adaptable to given space requirements;
3. no failure of water circulation;
4. suitability for high pressures and temperatures.

We distinguish (Figure 1) between forced circulation boilers (Loeffler,[1] La Mont and Velox boilers), in which the water is constantly kept circulating through the heating surface; and forced flow boilers (Benson and Sulzer single-tube boilers), in which just as much water is forced through the medium of the heating surface as is evaporated by it. The comparative power consumption of the feed (and rotary) pump is the highest with forced circulation and the lowest with natural circulation. The maximum difference, however, in working condensing only amounts to 1 per cent; in the case of the Loeffler boiler about 2 per cent of the power produced.

Translator's Note.—For words and designations appearing in diagrams see translated vocabulary at end of article.

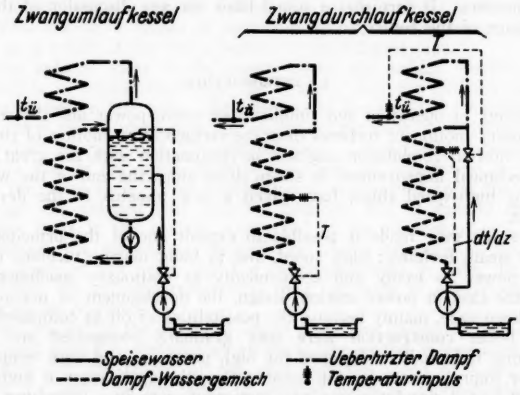


Fig. 1. WORKING DIAGRAM OF FORCED CIRCULATION AND FORCED FLOW BOILERS.

Zwangumlaufkessel	forced circulation boiler
Zwangdurchlaufkessel	forced flow boiler
———	feedwater
- - - - - - - -	steam-water mixture
——— — ———	superheater steam
≡	temperature impulse

[1] In the Loeffler boiler steam is pumped out instead of water.

(*b*) *Impure feedwater.* Forced circulation boilers can be washed like ordinary water tube boilers. In the case of forced flow boilers, water must either be constantly drawn off at a convenient outlet or a part of the heating surface must be washed from time to time. In forced circulation boilers, feedwater impurities can be separated in the boiler drum. In forced flow boilers these impurities, if they do not collect in the boiler or superheater, reach the turbine. Therefore, forced flow boilers require especially pure feedwater. Since the tendency to form boiler scale is reduced with increasing speed of circulation and these forced circulation boilers can be kept at from 1.5 to 2 meters per second at any pressure and under any load, forced circulation boilers are probably less susceptible to the formation of boiler scale than ordinary water tube boilers. Boiler and turbine, however, must always be considered collectively with regard to the feedwater, for when a specific lye concentration is exceeded, the turbine becomes dirty in all boiler systems, at least at high pressures, even when the boilers themselves operate faultlessly. From this standpoint we must also consider the condition of the plant when sea water enters the feedwater system due to leaking condensers. Marine installations with natural or forced circulation boilers evidently hold up better in the presence of this situation than installations with forced flow boilers.

(*c*) *Variations of load.* Since in forced circulation boilers the amount of construction material used for nonheating surfaces, as for instance, downcomer tubes, is small, and very small water tubes are permissible, and as the heat transfer is greater in small tubes than in large tubes, forced circulation boilers will be lighter than boilers with natural circulation, for the weight of the heating surface is about inversely proportional to the tube diameter. A further saving in weight can be obtained in the case of forced circulation boilers because the flue gases can better traverse the heating surface.

In large stationary power stations a sudden and unexpected load change in the whole boiler system from full load to no load is extremely rare. In the case of ships it can occur easily and often. Consequently, the behavior of a boiler under these conditions is a matter of great importance on shipboard. The sensitiveness to sudden removal of load is mainly determined by the quantity of steam in the boiler and in the superheater, and by the water content of the boiler, including the weight of water before the removal of the load, the said weight in turn depending on the type of circulation and the boiler load. The larger the quantity of steam the more time it takes for the steam, prevented from escaping when the load is suddenly removed, to produce the increase in pressure necessary for operating the safety valves. The greater the water content of the boiler, including the water admission, the longer it takes until both reach the temperature corresponding to the blow-off pressure. If we assume the same heating surface for all boiler systems, in the case of the water tube diameters for larger light marine boilers, the water content of the boiler, including the water admission under service conditions, with forced flow, amounts to about 75 per cent of the content in natural circulation, and with forced circulation to about 30 per cent (Figure 2). The steam volume contained in the evaporator and superheater, under the same assumptions, in the case of forced flow amounts to not more than 70 per cent of the content in the case of forced circulation or natural circulation. These values do not differ substantially from each other (Figure 3). A standard of measurement for the sensitiveness to sudden removal of load is furnished by the time which elapses until the safety valves begin to blow off, when neither the oil supply nor the feedwater supply is changed. According to Figure 4 all types of boilers are the more sensitive to sudden removal of load the higher the previous thermal

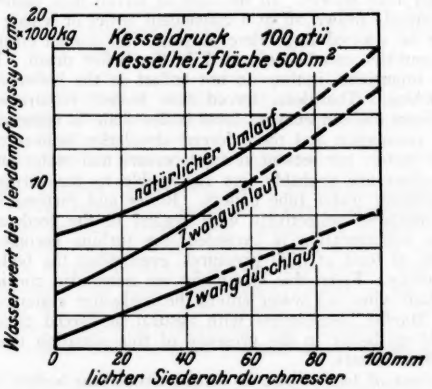


Fig. 2.—Water Content of Evaporator Unit of Various Types of Boilers with Water Admission Under Service Conditions.

(Boiler pressure 100 metric atmospheres; evaporation heating surface 500 m²; internal diameter of upper drum with forced circulation and natural circulation 1200 mm; internal diameter of lower drum with natural circulation 850 mm; cylinder length of drums 3100 mm.)

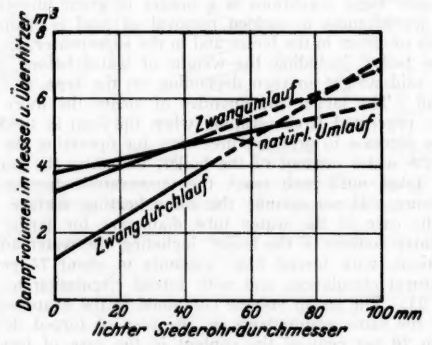


Fig. 3.—Volume of Steam in Evaporator Unit and Superheater of Various Types of Boilers.

(Under the same assumptions as Figure 2.)

output.[2] Forced flow boilers are the most sensitive. For instance, with a previous thermal output of 90 kg-m²h the regulating process in the case of forced flow should be completely terminated in 3.5 seconds at the very latest, in the case of forced circulation in 7.5 seconds and in the case of natural circulation in 10.5 seconds. But in land boilers with natural circulation it takes 22 seconds if the increase in pressure is not to exceed 5 per cent of the working pressure. In reality the periods are still shorter. Boilers carrying very high combustion chamber and heating surface loads, therefore, blow off much sooner when the load is suddenly removed than boilers carrying a low load. Boilers for high-speed coastal torpedo boats (Schnellboote) with internal water tube diameters of only 10 to 15 millimeters and high heating surface loads are especially sensitive to sudden changes of load. Therefore, boilers with forced circulation and natural circulation, other things being equal, need larger drums when the water tubes are small than when they are large, if the sensitiveness to load changes is to remain the same. These circumstances also explain why the same boiler system in this respect will prove satisfactory in one case and in another case not. At any rate, highly loaded forced flow boilers are very hard on their control systems, but are lighter than boilers with natural or forced circulation, the greater the cushion effect of the last two types is. However, in the example shown in Figure 4, the boiler with forced circulation, including water admission under service conditions, weighs approximately 0.25 tons per ton-hour maximum steam production; the boiler with natural circulation weighs approximately 0.4 tons more than the forced flow boiler.

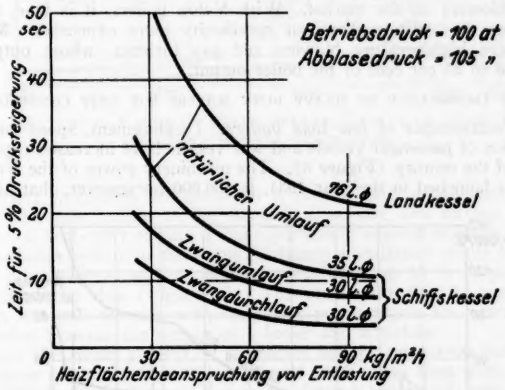


Fig. 4.—Time for Blowing Off of Safety Valves (set at 5 per cent Excess Working Pressure) of a Stationary Vertical Tube Boiler and Various Marine Boilers When the Normal Load is Suddenly Changed to No-Load Without Adjusting the Mechanism.

(Working pressure 100 metric atmospheres; blow off pressure 106 metric atmospheres.)

[2] In this case the boiler heating surface is identical with the evaporation heating surface.

Automatic boiler regulation has many advantages for high-speed vessels. Its cost and the complicated installation involved are the more negligible the larger the boilers. What is important is that in case of failure they can be operated readily by hand without any danger of serious accidents. This is done most easily with boiler systems that are operated like "normal" boilers according to gage and water level. The higher the boilers are loaded and the smaller the cushion effect, the more indispensable is automatic control, especially when many unexpected conditions must be taken into account. The importance of automatic boiler control and the realization that boiler and turbine are operated as a unit is also evident from the fact that the simultaneous control of the boiler and machinery installations and the idea that in maneuvering, the master control should be assigned to the boiler installation, is becoming more and more the subject of discussion.

(*d*) *Advantages of high furnace loads and flue gas velocities.* Forced circulation boilers can be built for maximum flue gas velocities of from 25 to 50 meter-seconds and equipped with a blower, which is sufficient to make up for any loss of draft and which makes a special induced draft installation dispensable (high-speed boilers). Or, as in the case of the Velox boiler, the combustion can be effected at an excess pressure of from 1.5 to 2.5 atmospheres, the blower can be driven by a gas turbine through which the waste gases of the boiler flow and with a part of the pressure drop, and flue gas velocities of from 200 to 300 meter-seconds can be produced. Space requirements and weight are particularly small when much higher furnace loads are applied than are customary and admissible in the case of solid fuels. The Velox boiler, with values up to 8 million kcal-m^{3}h, at present is in the lead in this respect. High-speed boilers get along with the low pressure blowers on the market. With Velox boilers, it is true, the heating surfaces are still smaller, but specifically more expensive. Moreover, they require high-pressure blowers and gas turbines, whose output must be from 20 to 25 per cent of the boiler output.

III. THE IMPORTANCE OF HEAVY DUTY BOILERS FOR SHIP CONSTRUCTION.

(*a*) *Disadvantages of low load boilers.* Displacement, speed, and power consumption of passenger vessels and war vessels have increased rapidly since the turn of the century (Figure 5). The machinery power of the *Normandie*, which was launched in the year 1934, is 160,000 horsepower, that of the air-

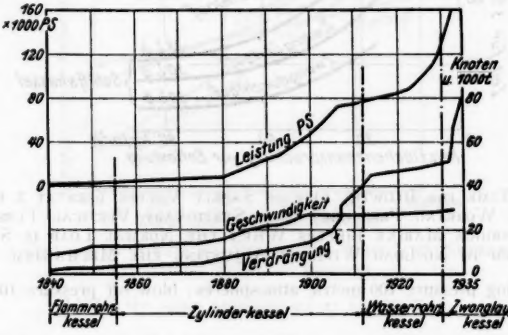


Fig 5.—Increase of Displacement, Speed, and Machinery Power of Passenger and War Vessels Since 1840.

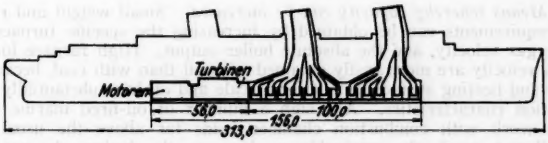


Fig. 6.—Space Requirement of Boiler System and Total Machinery Installation on the 80,000 Ton Steamer "Normandie" with 160,000 Horsepower.

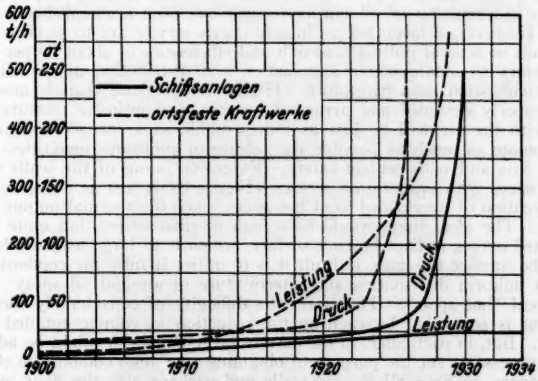


Fig. 7.—Maximum Value of Pressure and Output of Marine Boilers and Land Boilers Since 1900.

plane carriers *Lexington* and *Saratoga* is even 180,000 horsepower. Consequently, water tube boilers of the standard type, size, and furnace load (0.4 to 0.5 million kcal-m^{3}h) require a disproportionate amount of space. For example, the boiler system or the whole machinery installation of the *Normandie* (160,000 horsepower), with 29 boilers, takes up from 32 to 54 per cent of the length of the ship (Figure 6). The reason for this is, among other things, as was still the case with stationary power plants ten years ago, the disproportion between the output of a boiler and a turbine.

Although the steam generation of marine boilers since 1900 has been increased about five times, it is still at present much lower than with stationary boilers (Figure 7), at least as far as the largest models of both types are concerned. But a trend toward larger units is unmistakable.[3] The *Imperator*, built in 1912, with 61,000/84,000 horsepower machinery and 46 boilers, had 1330/1830 horsepower per boiler. The *Conte Di Savoia*, which was launched in 1930, has 10 boilers of 10,000/13,000 horsepower each, making a total of 100,000/130,000 horsepower.

[3] In the near future, however, there will be no demand in the shipbuilding industry for the giant boilers set up in some superpower stations.

(*b*) *Means whereby capacity can be increased.* Small weight and reduced space requirements can be obtained by increasing the specific furnace load, the flue gas velocity, and the absolute boiler output. High furnace load and flue gas velocity are more easily obtained with oil than with coal, because the furnace and heating surface cannot form scale and oil has substantially better combustion characteristics. Although a number of oil-fired marine boilers already work with combustion chamber loads far above the usual loads we shall not reach the attainable as long as the boilers do not automatically adjust themselves to variations of load as rapidly and without loss as internal combustion engines; as long as they cannot stand high specific stresses for a long time without damage; and as long as they do not work over a large load range with high efficiency. All these requirements can be fulfilled if the means at present available are systematically employed.

In the construction of oil burners, much has been accomplished in recent years. However, if large boilers in continuous service are to work with furnace loads of several million kcal-m^{3}h and efficiencies of about 90 per cent, it is necessary to obtain better atomization and distribution of the oil in the air of combustion than heretofore. Higher oil pressure than is mostly the case, properly designed and arranged burners, and intimate mixture of the flame with the air will be just as indispensable as a furnace design which will promote as much as possible the release of enormous quantities of heat without loss and with perfect safety. Extensive lining of the walls of high load furnaces with evaporation surface (Figure 8) is just as indispensable as the prevention of overloaded local hot spots, since the thermal output is high anyhow. The ideal thing would be a high thermal output, but quite equally distributed over a radiant heating surface, which is as large as possible. The larger the furnace the more difficult it is to utilize it fully for combustion; to obtain a uniform distribution and intermixture of air and oil spray; and to avoid local "hot spots". Therefore, the difficulty of considerably increasing its output is somewhat lessened by the reduction in volume entailed by the increase. But, in particular, in the case of large boilers, it might be advisable or even necessary, for the purpose of obtaining very high combustion chamber performances, to have all the sidewalls and perhaps also the floor available for the admission sections of the air of combustion and of the burners. Furthermore, the furnace must be so designed that the flame can develop undisturbed, and can burn out completely before the products of combustion enter the flues.

These requirements are closely connected with the water circulation of the boiler, for the following reasons:

(*a*) A radiant heating surface under high load must be cooled particularly effectively;

(*b*) With very high furnace loads, secondary combustion is more likely to occur than when a medium load is carried, and it exposes to danger such parts of the heating surface as require a very low rate of circulation in undisturbed operation;

(*c*) With forced circulation it is constructionally easier to cool the furnace and design the furnace, taking into account the requirements of furnace technique. The great adaptability of forced circulation boilers to conditions of space, since they can be, as it were, built "round the corner," is shown in Figure 9. Forced circulation is superior to forced flow and natural circulation in this connection, because it guarantees a sufficient supply of water to the entire heating surface, independent of load conditions and faultless combustion. In particular, secondary combustion, caused by defective or incompetently handled burners, cannot convert downcomer tubes into upcomer tubes, as in the case of natural circulation, and thereby expose the furnace to danger.

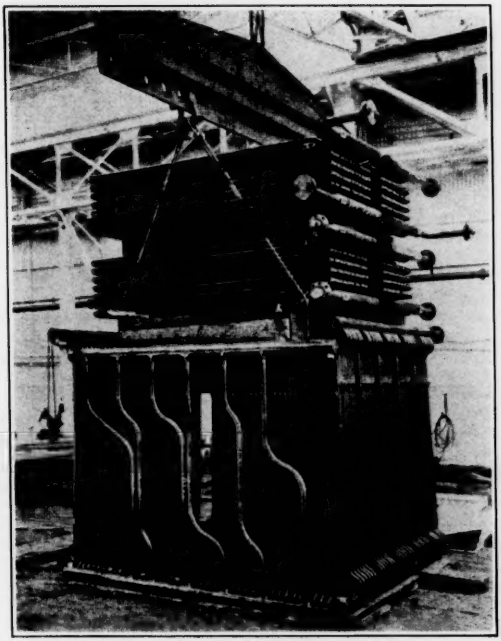


Fig. 8.—Cooled Combustion Chamber, Evaporator and Superheater of a 90 atm. Benson Boiler of the Express Liner "Potsdam."

(Surface of evaporation, 590 m^2, of which 90 m^2 is cooling heating surface and 250 m^2 superheater.)

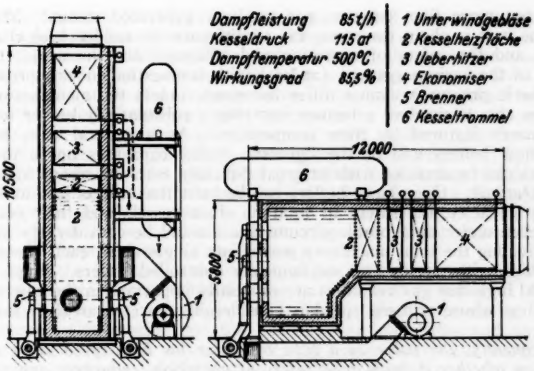


Fig. 9.—Stationary 115 Metric Atm. La Mont High Speed Boiler of Vertical and Horizontal Design.

(Evaporation 85 t-h; steam temperature 500 degrees; efficiency 85.5 per cent.)

1—Undergrate blower.
2—Boiler heating surface.
3—Superheater.
4—Economizer.
5—Burner.
6—Boiler drum.

In my opinion, the greater simplicity with which hand operation can be resorted to when the mechanism is out of order, the better maneuverability due to the greater storage effect, and other advantages of boilers with natural and with forcd circulation, fully compensate for the drawback of having to have boiler drums.

Boilers with natural circulation have in their favor their great simplicity, and that their circulation is entirely independent of mechanical aids. A temporary failure of the pumps, which is already very serious with forced circulation boilers, does not matter with them. A sudden load change affects them the least and their mechanical control is attended by the fewest difficulties (see Figure 4).

(*c*) *Furnace load and unit weight.* Although the importance of unit weights must not be over estimated, since they are often determined with very arbitrarily chosen furnace loads and under assumptions which vary greatly, and they are only one of the items of importance in the appraisal of a steam generator, nevertheless, if properly employed, they furnish a good picture of the development and general tendency.

The unit weight (and also the space requirement) during the last twenty years has been very much reduced by improvements in design, development of larger units and, in particular, by higher furnace loads. With furnace loads of several million kcal/m³h, in the case of boilers generating but a few ton-hours of steam, inclusive of economizer and preheater, unit weights as low as about 0.8 per ton-hour of steam can be obtained. Velox boilers, including rotary pump, blower, gas turbine and mechanical control, weigh from 1.3 to 1.5 tons in the case of land boilers, and in the case of marine

boilers not more than 0.8 tons per ton-hour generated steam.[4] Moreover, when the cost is about the same, the sensitiveness to sudden load changes is similar, and the safety of operation and efficiency are the same; the unit weights of the various systems (at least with combustion under approximately atmospheric pressure) cannot differ too much, unless the manufacturers are somehow able to produce a furnace carrying a substantially higher load than the furnaces featured by their competitors. As a general rule, however, forced flow boilers will be the lightest. Boiler capacities up to 75 or 100 ton-hours can be obtained without great difficulty with the means indicated.

(*d*) *Outlook.* Once large boilers can be built that are as safe as those of ordinary capacity, the safety of multiple shaft vessels and their maneuverability even under unfavorable circumstances could be considerably improved by subdividing the total machinery power into single units, each consisting of one turbine with one or two mechanically controlled boilers. High furnace loads and high flue gas velocities are especially important in the case of high-speed ships whose cruising speed is considerably lower than their maximum speed.

Consequently, the value of a type of boiler for high-speed ships depends largely on whether it, with good safety of operation, endurance and fuel consumption on a voyage of many hours, can stand very high furnace loads, is unaffected by failure in the method of firing and the occasional entry of seawater into the feedwater system, can be easily adapted to the space available, is suitable for high performances, and is comparatively insensitive to sudden load changes. But the primary consideration in developing light, compendious boilers must always be high furnace loads and the development of efficient burners. A proper supply of oil and air of combustion, thoroughly intermixed in a properly designed furnace, assured and undisturbed water circulation in the entire heating surface, and comparative insensibility to the entry of seawater and sudden load changes are further requirements, which apply to all boiler systems indiscriminately, although they cannot be complied with as readily and fully with each type of boiler or boiler system. It is, therefore, not probable that a specific system will furnish the universal boiler, although, all things considered, forced circulation on ships has far better prospects than on land. The future must show whether combustion under considerable excess pressure, which would change the design of the entire boiler installation, would pay also in the case of "normal" boilers, for the purpose of obtaining higher performances.

In deciding between boilers with natural circulation, forced flow and forced circulation, however, we must not only take into account their individual characteristics enumerated above, but also whether they are destined for very large or very small vessels and whether the primary requirements are very high maximum performances, very good maneuverability, extremely light weight, very small space requirement, or whether very high efficiency is essential. Since only very few special marine boilers have been in operation for any length of time, the good or bad results obtained should be appraised very carefully in order to determine whether we are not dealing with accidental results, or phenomena which are only loosely connected with the actual "boiler system."

The progress made in the field of steam turbines is just as important as the progress in boilers. While the 30,000/42,000 horsepower turbines of the *Imperator* only had a speed of 150 R.P.M., the high pressure stages of the 6250 horsepower turbines of the *Tannenberg* operate at 18,000 R.P.M. and the 13,000/16,300 horsepower turbines of the *Scharnhorst* at 3120 R.P.M. In addition to the reduction gear, which furnishes the lightest installations,

[4] The unit weight of Velox boilers includes the weight of the blowers, the gas turbine, the rotary pump and the mechanical control system.

the electric transmission of power has been adopted with great success by German builders of marine machinery. Silence, even at slow speed, economical operation, connectability of the turbines to all the propeller shafts, full machinery power when reversing, and other advantages are involved. High furnace load and some other improvements in the boilers, combined with high speed of the turbines made possible such economy in weight and space requirements that steam turbine installations already, at about 1,000 horsepower, have become serious competitors of internal combustion engines. By employing high power boilers and high speed geared turbines to-day weights of the total machinery installation without shafts and propellers are obtained as low as 35 kilograms per horsepower in the case of express liners, about 20 kilogram-horsepower for war vessels, and 10 kilograms per horsepower for high-speed coastal torpedo boats (Schnellboote).

As regards the increase in the output of marine boilers, with high furnace loads favorable results are obtained the quickest and probably at the least expense by conducting tests on a land boiler installation especially built for that purpose. Cooperation and the exchange of knowledge and experience can contribute largely to saving unnecessary expenditures and avoiding disappointments, and can quickly lead to successful results.

VOCABULARY.

(To read diagrams.)

Ablasedruck	Blow off pressure.
Betriebsdruck	Working pressure.
Beruehrungsteil	Contact part.
Dampfvolumen im Kessel und Ueberhitzer	Volume of steam in boiler and superheater.
Direkt gekuppelt	Direct coupling.
Doppelenderkessel	Double-ended boiler.
Druck	Pressure.
Einenderkessel	Single-ended boiler.
Einrohr	Single tube.
Eko	Economizer.
Flammrohrkessel	Flue tube boiler.
Getriebe	Geared.
Geschwindigkeit	Speed; velocity.
Heizflaechenbeanspruchung vor Entlastung	Thermal output before removal of load.
Kesseldruck	Boiler pressure.
Kesselheizflaeche	Boiler heating surface.
Knoten	Knots.
Lichter Siederohrdurchmesser	Internal diameter of water tubes.
Landkessel	Land boiler.
Leistung PS	Horsepower.
Luvo	Preheater.
Nachueberhitzer	Re-superheater.
PS	HP.
Natuerlicher Umlauf	Natural circulation.
Sattdampf	Saturated steam.
Schiffsanlage	Marine installation.
Siederohr	Water tube.
Steilrohr	Vertical tube.
Strahlungsteil	Radiation unit.
Um/Min	R.P.M.

Verdraengung	Displacement in tons.
Wasserrohrkessel	Water tube boiler.
Wasserwert des Verdampfungssystems	Water content of evaporation system.
Zeit fuer 5% Drucksteigerung	Time for 5 per cent pressure increase
WPS	SHP.
Zwangdurchlaufkessel	Forced flow.
Zwangdurchlaufkessel	Forced flow boiler.
Zwangumlaufkessel Zwanglaufkessel	Forced circulation boiler.

MISCELLANEA OF ITEMS OF INTEREST TO NAVAL ENGINEERS

SELECTION OF COLORS FOR SIGNAL LIGHTS. Technical News Bulletin, National Bureau of Standards, December, 1936.

At the request and with the financial support of the Bureau of Aeronautics, Navy Department, an investigation was undertaken by H. J. McNicholas at the Bureau to determine the best color limits for signal lights constituting a six-color system. The choice of suitable colors for any signal system is determined primarily by the number of colors required and the service conditions. In the present application the lights must be readily identified over a distance of approximately 1500 feet, under weather conditions varying from a clear atmosphere to light haze. The signals are seen and identified as point sources of low intensity, and the colors are limited to those obtainable by combinations of an incandescent lamp and colored-glass cover globes.

Under these service conditions the problem is reduced to a choice between two six-color systems. One system consists of red, orange-yellow, white, green, blue, and purple. The other system consists of red, orange, yellow, white, green, and blue.

The best ranges of each color were determined and comparison made between the two systems. The work was done on an outdoor test range by groups of normal observers, under test conditions closely simulating those required in service. Various test colors were exhibited at different signal intensities in random order, and observers were asked to assign each color to one of the six permitted color classifications. In this way approximately 58,000 single observations were recorded in the selection of the colors and their tolerance limits.

As described in the December number of the Journal of Research (RP956), it was found that the orange and yellow were the least distinctive as signal colors when both are used with red and white. Permissible tolerances were also found to be too restricted for easy reproduction of the colored glassware. Furthermore, these orange and yellow colors are not stable with varying distance and appear shifted toward the red as the distance is decreased (higher signal intensity).

Considerable difficulty was experienced in the discrimination between green and blue and it was found that a highly saturated "sextant" green was required to gain the maximum distinctiveness from a saturated blue. At long distances (low signal intensities) a definite tendency to confuse the green and blue is unavoidable.

Purple, in general, is not a good long-distance signal color because of the low transmission of light by all purple-glass cover globes and the well-known dichromatic nature of this signal when seen as a very small source.

This color proved to be very distinctive, however, when the signal intensity was made comparable with that of the other colors. This required a lamp intensity at least 21 times that required for white or yellow signals.

On the whole, the tests favor the selection of red, orange-yellow, white, green, blue, and purple as the best six-color signal system for the required service conditions.

DESIGN OF DESTROYERS. Shipbuilding and Shipping Record, London, England, December 24, 1936.

The design of destroyers has become a matter of great discussion among naval officers, the question being whether the time has not arrived to split this type into two or three entirely different ships according to the functions which they are expected to fulfil. During the forty-three years of its existence the destroyer type has undergone more changes, and has had more functions added to its purpose, than any other type of man-of-war. The original idea was that it should be used for destroying the small torpedo boats which were attracting so much attention, the fact that it could act as a very efficient torpedo boat itself on occasion being something of an afterthought. The principal lesson of the Russo-Japanese War was that this role of torpedo boat was one that it could fulfil with the greatest efficiency, and it came to be regarded as its principal purpose. This was especially so in Germany, where they never used the word destroyer but called the type "big torpedo boats" and designed them accordingly. Then in the war they were called upon to carry out every imaginable job and the result of this, and subsequent study, is that the type has become terribly expensive. A considerable proportion of the cost is in the gunnery department, where the instruments are as elaborate as those of a small cruiser. So some practical men think that money would be saved, and destroyers provided in the numbers required by the service, if they were split up. One type would be designed specially for torpedo work with the minimum of guns; possibly the new multiple-barrelled pompoms might be sufficient for this purpose. The vessels whose particular functions demanded gunfire, as they often did in the war in the North Sea, would be given the same gear as the modern type, but weight and money would be saved in the torpedo equipment which would be kept down to a minimum. The third type would be specially designed for anti-submarine work.

STEEL FOR MODERN STEAM CONDITIONS. Combustion, New York, N. Y., November, 1936.

L. Sanderson, discussing this subject in the October issue of Engineering and Boiler House Review, refers to the use of steel containing 39 per cent nickel and 10 per cent chromium as particularly suitable for the high peripheral speeds of low-pressure turbine blading in order to lessen the rate of erosion and corrosion and at the same time provide the necessary toughness and mechanical strength. In one instance where nickel steel blades lasted only 7600 hours the 39/10 steel blades have been in service nearly six years without being appreciably affected.

CRUISING DIESEL ENGINES IN GERMAN WARSHIPS. The British Motor Ship, London, England, December, 1936.

It is understood that the new German battleship *Scharnhorst* and the sister ship *Gneisenau*, of about 26,000 tons displacement, although having

geared turbines for main propulsion, will be equipped with cruising Diesel engines, to be utilized in normal service under peace conditions. The German Naval authorities already have considerable experience with a similar system on a smaller scale, and in view of the enormous saving which could be effected for a period of about nine-tenths of the life of a battleship, it is to be presumed that the British Admiralty will seriously examine the possibilities of a similar arrangement in the battleships which are now being laid down in this country.

NAVAL SHIPBUILDING PROGRAM BENEFITS ENTIRE COUNTRY. Boston Navy Yard News, November, 1936.

Shipbuilding costs are made up approximately as follows: 40 per cent labor plus 40 per cent material plus 20 per cent overhead equals 100 per cent. About 40 per cent of the cost of building a ship goes to labor at the site. Of the 40 per cent cost of material, about 70 per cent goes to labor from the site, namely, in the field, all the way back to the forest and the mines. Of the overhead cost, about 80 per cent goes to labor. Therefore, about 84 per cent of all the money goes to labor in the shipbuilding industry.

The money appropriated for the Navy, whether for pay, food, new ships, maintenance, or other purposes, is nearly all returned very promptly to the general channels of commerce and industry. It therefore serves as a stimulus to the general business of the country.

In the recent construction of naval vessels, expenditures have been made amounting to $90,000,000 for materials of the classes listed:

Bolts, nuts, washers and rivets	$ 404,952
Cast-iron pipe and fittings	569,931
Electric wiring and fixtures	1,681,657
Electrical machinery and apparatus and supplies	9,509,463
Elevators and elevator equipment	235,193
Engines and turbines	9,838,347
Forgings, iron and steel	4,284,483
Foundry and machine shop products	7,036,218
Glass	118,909
Hardware	117,053
Heating and ventilating equipment	486,010
Lumber and timber products	468,702
Machine tools	730,879
Metal doors, shutters, window sash and frames	1,102,889
Paints and varnishes	127,972
Petroleum products	138,814
Planing-mill products	5,268
Plumbing fixtures and supplies	141,678
Pumps and pumping equipment	1,822,567
Steel products	35,521,308
Tiling, floor and wall	27,136
Wall plaster, wall board and insulating board	100,155
Wire and wireworks products	434,050
Other materials	15,754,992

An analysis shows that these materials are received from every State in the Union.

PERFORMANCE OF THE LJUNGSTRÖM NONCONDENSING TURBINE LOCOMOTIVE. Engineering, London, England, December 25, 1936.

In the account of the World Engineering Congress in Japan, given in Engineering, volume cxxviii, page 853 (1929), will be found a comparison of the performance of a Ljungström turbine locomotive and one of the more usual piston type. The data there given may be amplified by some more recent figures. Three turbine locomotives built to the designs of Messrs. Aktiebolaget Ljungströms Angturbin, Stockholm, are now in regular service on the Grangesberg-Oxelösund Railways, Sweden.

These locomotives, of the 2-8-4 type, without a separate tender, have the turbines placed transversely across a platform between the front buffer beam and the smokebox door, and driving a jack shaft from which transmission is made to the four wheels on each side by a coupling rod. Unlike some of the earlier Ljungström engines, these locomotives are non-condensing. The adhesion weight is 72 tons, and the first of the three locomotives, which was put into service at the beginning of 1932, has yielded very satisfactory results in the hauling of heavy iron-ore trains having a dead load of 1750 tons behind the tender. No assistance has been found necessary in negotiating long grades of 1 in 100, and since the date mentioned the engine has run 135,000 miles in low-speed heavy freight traffic, of which 71,500 miles were run before general repairs were needed.

We are informed that with the piston engines on the same railway the distance run before general repairs are necessary is between 31,000 miles and 36,000 miles. The upkeep costs of the turbine locomotive would therefore seem to be low. Comparative tests between the two classes of locomotive carried out in 1933 showed a saving of fuel of 23.8 per cent with the turbine locomotive. While this saving is consistently maintained, it is stated that the turbine locomotive is valued chiefly for its capacity for hauling considerably heavier trains, thus relieving the very congested traffic now obtaining on the line.

PROPELLER CAVITATION AND VIBRATION. Shipbuilding and Shipping Record, London, England, December 30, 1936.

A noted authority on propellers recently expressed the opinion that three disturbing factors were definitely linked together, namely, cavitation, vibration and erosion. In Prof. Lewis's work on vibration, which has been receiving attention on both sides of the Atlantic, vibration has been traced to the disturbing influences of propeller bossings on the flow. In the case of the *Normandie*, rapid variations of the wake value in the region of the bossings were discovered by tank experiments, and alterations subsequently carried out brought about considerable modifications to these variations with corresponding diminution in the vibratory forces. Prof. Lewis pointed out, in his recent paper, to which reference was made in our columns recently, that, although such influences were at work, cavitation might also be a primary cause, but it could not be elucidated in the particular experimental work in which he had been engaged. It is known that the erosion difficulty has been greatly overcome by the careful designing of propellers, and it is claimed that this is the direct result of the obviation of the formation of cavities by attention being paid to the characteristics of the leading edges of the screws. When cavities are formed, enormous impacting forces are generated which are the direct causes of erosion, and which may also be the part causes of vibrations. From this standpoint, the cures for cavitation

erosion and vibration are all linked together in the design of the screws. Should this be the case, and the type of blade section be found which obviates the formation of cavities, the troubles which are attached to the powering of ships of high speeds will be greatly minimized.

SMALLEST BALL BEARING IN THE WORLD. Machinery, New York, N. Y., January, 1937.

Frequently we have referred to the largest developments in various branches of engineering. An example of the opposite extreme recently came to our attention, when we had the opportunity to inspect what doubtless is the smallest ball bearing in the world. This tiny ball bearing was developed by the engineering departmnt of the Split Ballbearing Corporation of Lebanon, N. H., a company that devotes itself largely to the manufacture of special bearings for difficult applications.

At the request of another manufacturer, the corporation recently undertook the investigation of equipment suitable for the manufacture of miniature-sized ball bearings, for which there is an increasing demand in fine precision instruments. The problem was made more difficult by the fact that the extreme accuracy required had to be achieved entirely through machining processes, as it was impossible to grind such exceedingly small parts as were encountered in this bearing. The work was accomplished largely through the use of novel electrical and magnetic controls.

The completed bearing is almost exactly 1/16 inch outside diameter and 1/32 inch in width—actually smaller than the head of a common pin. The bore is 0.023 inch. The balls in this midget bearing were furnished by the Norma-Hoffmann Bearings Corporation, Stamford, Conn., and are also examples of unusual precision. They are only 1/64 inch in diameter and have the accuracy of high-grade measuring gage-blocks. The mechanical work on the bearing was done by the consulting engineer of the Split Ballbearing Corporation, Winslow S. Pierce, Jr., who is the originator of the fracturing process used by the company in the manufacture of their regular ball bearings of the divisible race type.

The miniature bearing is now installed in a Waltham watch as a substitute for the jewel at the end of the second-hand shaft. It is actually so much smaller than the jewel it replaced that it was necessary to make a bushing to go around the outer race.

DETECTING CRACKS AT RIVET HOLES. Combustion, New York, N. Y., December, 1936.

This subject is discussed at length by H. Wilhelm and H. Elsasser in a recent publication of Vereinigung der Grosskesselbesitzer (Berlin). It appears that several methods of detecting such cracks are in use abroad. One consists of removing certain rivets, reaming and polishing the holes, and then subjecting them to visual inspection, but for this means a trained eye is required. A second method, called the Baumann method, requires polishing of the surface which is then wetted with a sulphide solution that penetrates the cracks. After drying the surface, a bromine-silver coated paper is pressed against the surface and any solution remaining in the cracks registers on the paper. This method also requires considerable experience for good results.

X-raying is also employed. This does not necessitate removal of the rivets and one exposure will cover up to twenty rivets. For plate thicknesses over 2¾ inches gamma rays are necessary for definite results. This method has

one shortcoming in that the direction of the rays and that of the cracks frequently is not the same and reading of the film in such cases requires long experience for the detection of all cracks.

It has been found that cracks in a steel plate placed in a strong magnetic field will cause iron filings to arrange themselves along the edges of cracks. However, in order to cover all possible cracks it becomes necessary to set up two magnetic fields, normal to one another. While this procedure is reliable it has the disadvantage of attaching and moving the heavy electro magnets; also, direct current is necessary and may not always be available.

A magnetic powder method of detecting cracks has more recently come into use and seems to combine effectiveness with convenience. With this the rivets are removed and the holes reamed but polishing is not necessary. Into the rivet hole is inserted a conductor through which flows a heavy alternating current of low voltage, about 2 volts, and around this is poured mineral oil containing specially prepared and dyed iron powder. This powder will accumulate as a distinctly visible ridge over a crack. The apparatus weighs only about 55 pounds, is compact and can be inserted into the drum through the manhole. Licenses for the use of this method are handled by the German Government's Materials Testing Bureau which developed the procedure.

A somewhat similar method is understood to be in use by one of the turbine builders in the United States.

JANE'S FIGHTING SHIPS. 1936. Edited by Francis E. McMurtrie. London: Sampson Low, Marston & Co., Ltd. 13 inches × 8½ inches × 1¼ inches. 568 pages. Price 42s. net. Shipbuilding and Shipping Record, London, England, December 30, 1936.

The world-wide sources of information enlisted in the work of compiling "Jane' seem this year to have provided Mr. McMurtrie with an unusual wealth of detail. Certain it is that two days' study of the new volume has brought into focus the world-position in naval shipbuilding on the eve of the end of the Washington limitations. The activity of the shipbuilding yards of all the Powers is shown very clearly, and a few moments' calculation gives us a total of 368 warships from battleships to submarines, building or about to be laid down for the six principal navies. This leaves out of account all auxiliaries, motor torpedo boats, and similar small craft.

There is still, of course, considerable secrecy about new designs, but "Jane" has obtained the principal characteristics of all the vessels under construction. Thus, despite the strong rumors to the contrary in engineering circles, the new British battleships are here credited with 30 knots speed. The French *Richelieu* class are given as 33-knot vessels (160,000 horsepower). It is interesting to note the difference in practice among the Powers in regard to main armament. Britain and Germany are mounting the 14-inch gun as agreed in the 1936 London Treaty. The French vessels are to have eight 15-inch guns, the Italian *Littorio* class nine 15-inch, and the American ships 16-inch.

In cruisers the most interesting disclosure is in the drawing of the British *Southampton* class. These vessels are to have hangars as an extension aft of the bridge structure with the forefunnel carried up between them. A new type of athwartship catapult is fitted between the funnels. This design appears to be unique among warships at present, and it will be interesting to see whether any other Powers adopt it. The whole question of aircraft equipment for fleets is playing an important part in design today, and the details of new aircraft carriers in "Jane" this year are a striking commentary on the opinion so loudly expressed a year or two ago, that this class of ship

was doomed. The new British vessels are to be of 22,000 tons, the Germans of 19,250 tons, two of the Americans of 19,900 tons. Japan is building a smaller type of 10,000 tons, and a third American vessel is to be of 14,700 tons. France and Italy are still building none.

The new American destroyer designs show a strong influence from British practice, but their cost is startling. Flotilla leaders are given as £800,000 each and destroyers as £750,000. British costs for similar type are about £330,000 and £290,000 each respectively.

One persistent legend should be finally killed by the new "Jane." It is there recorded that the Italian Navy possesses 39 motor torpedo-boats and has 25 more under construction. Perhaps the scaremongers who have glibly written about Italy's hundreds of mosquito craft will kindly note the correct figures.

There are no remarkable disclosures of high speeds recorded this year apart from the French destroyer *Terrible*, which is credited with 45.25 knots on trial. The Italians, who for some years set up one record after another, appear to have restrained their ardor. In the new *Oriani* class, for example they are content with 48,000 horsepower and a designed speed of 39 knots as against the 71,000 horsepower and 44 knots that they were showing us five years ago.

"Jane's Fighting Ships" is one of the most fascinating books in the world for the student of naval affairs. One can always browse in it and come across some new fact, and that with the clear conviction that it is a fact; for the standard of accuracy in "Jane" is unapproached by any similar work produced abroad.

RELATIVE PRICES OF BOILER OIL AND DIESEL FUEL. The British Motor Ship, London, England, January, 1937.

It would be helpful for shipowners to gain some idea of the probable price differential between Diesel fuel and boiler oil in the coming years. Dr. Blache has made an interesting comment on the situation as a result of an investigation while in America recently, when he visited some of the oil refineries. Most crude oils have a relatively small percentage of petrol, but the demand for petrol is extremely large, and if it could be produced only by straight distillation there would be a tremendous surplus of light and heavy gas oil from such distillation. Hence, both the lighter and heavier gas oils are repeatedly "cracked" again into petrol and a heavy oil which is mainly used under boilers.

Owing, however, to the very rapid increase in the employment of small high-speed oil engines for vehicles, caterpillars and tractors, the demand for a very light gas oil (considerably lighter than that required for marine Diesel engines) is increasing at the expense of petrol. The result is that a large amount of light oil will be used in the future for this purpose and will not be cracked into boiler oil and petrol. For the supply of this quantity of light gas oil and the correspondingly reduced amount of petrol for the particular purposes in question, the same amount of heavy Diesel oil will be produced as at the present time. There will, however, in Dr. Blache's opinion, be less residual boiler oil distilled from every ton of crude oil treated.

This seems a logical view of the situation, and if it represents the trend of events the price of boiler oil relative to Diesel fuel will rise. Some may possibly think that the employment of these high-speed Diesel engines will not be sufficient to have an influence on the problem, but the extent of their adoption is scarcely realized. For instance, Diesel-engined caterpillars to the number of over 20,000 have been built by one firm in America in three years.

FOR SCHOLARLY READERS. The Industrial Bulletin, Arthur D. Little, Inc., Cambridge, Mass., January, 1937.

A revolution is impending, hatched in the calm alcoves of the world's libraries. A means of recording, storing and distributing the written word, said to be the most important discovered since the time of Gutenberg, is being developed and adopted by conservative bibliophiles in charge of important book collections, from the great library of the British Museum in London to that established by Huntington funds in Los Angeles.

The underlying principle of the new practice is simple—the book, newspaper or manuscript page is photographed on a microfilm and thus minified to perhaps as little as two thousandths of its original area. It has been estimated that by such means the books of the New York Public Library could be kept in the space now used for its card index. Newspapers, as invaluable records of current history, can thus be preserved at about the present cost of binding, and on a film reported by the Bureau of Standards as comparable to record paper in its permanency.

One of the microfilm pioneers, the radio inventor, Fessenden, considered this matter of permanency as a principal objective. He reported platinum prints from microfilms on thin quartz, suggesting reproduction of the Bible in a cubic inch of platinum on quartz that would stand ageing, fire and weather, and preserve to distant posterity corner-stone and other records. Over fifteen years ago he had a reading machine of his own design for the small films. Another pioneer was Rear Admiral Fiske, and a second Navy officer is responsible for one of the best of the more recent mechanisms. A prominent librarian has worked with photostat paper instead of film. No method is yet accepted as fully perfected, but 1937 is expected to see the first commercial introduction of acceptable full equipment by libraries. Closely related apparatus, made by an Eastman subsidiary, is now in regular use in many banks, recording all checks.

The magnifying and reading mechanism is the present limiting factor in further extension of photographic library service: the film must not be scratched or overheated; the reading device should be adaptable to the numerous types of film record now obtainable from different sources, and it should be possible to read for appreciable periods without excessive eye strain. No one device at present meets these and other prerequisites at a first cost permitting wide adoption. The leading optical instrument companies, however, are actively interested and now have inexpensive devices suitable for individual use, particularly for short periods.

One corporation, with strong backing, proposes the publication of film books, suggesting the New York telephone directory on the palm of a hand and a law library in a suitcase. Copyright considerations, which affect all film copying work, are here of special importance. Another American company has cameras in Europe's leading libraries and will deliver copies of single pages or complete books from their shelves. The Bodleian, the Bibliothèque Nationale and the Vatican collections become available to individuals the world over.

The best organized microfilm service now available is probably that offered by the documentation division of Science Service, through which the extensive library of the Department of Agriculture may be drawn upon at nominal fees for the films. For occasional reference inexpensive reading devices are available from scientific-supply houses and other sources, or the more elaborate reading machines may be purchased for more extended use. Scientific papers may now be published on film for distribution too limited for the usual journals, and business documents may be copied for record and filing. More extended and more startling possibilities for microfilm applications are being investigated experimentally.

Industrialists see in the microfilm a new tool for their engineering and research departments. The need for following new development as reported in distant centers of technical activity has increased enormously in recent years. Foreign and domestic technical literature may be tapped more readily and more inexpensively once the new method becomes generally adopted. More complete files in special subjects may be kept and used effectively. Already Yale, Brown and other universities have taken healthy first steps in utilizing microfilm, and the National Archives has a qualified specialist in charge of photographic reproduction and is equipped for microfilm. The librarian of the University of Chicago is chairman of a microfilm committee of the American Library Association.

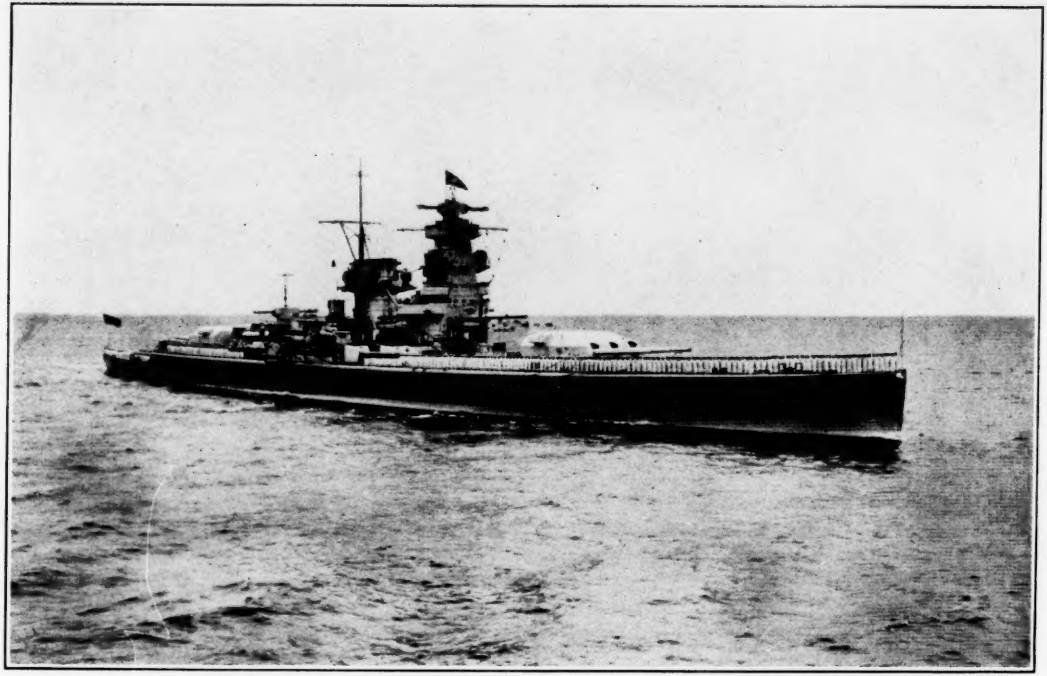
It takes little imagination to visualize what might be some of the business possibilities of this new treatment of the written word. Municipal libraries may adopt it, schools may use it in various ways, and reference and other books be sold in the miniature form. With expansion into any one of these or other consumer fields, the business of supplying film, copying and reading equipment may create a new industry.

GERMANY'S LATEST MOTOR BATTLESHIP. The British Motor Ship, London, England, January, 1937.

Although completed some time ago, photographs of the German motor battleship *Admiral Scheer* have not been published in this country, and the reproduction above is, therefore, of considerable interest, particularly as it reveals several features of difference compared with the *Deutschland,* of which many illustrations were given in this journal of September, 1933. Generally speaking, the two ships and the *Admiral Graf Spee* are similar vessels, known as the *Deutschland* class, their size being limited under the Versailles Treaty to 10,000 tons displacement without fuel, or approximately 12,000 tons displacement including fuel and water. Since the Versailles Treaty has gone by the board, Germany has laid down other battleships of about 26,000 tons, the *Scharnhorst* and *Gneisenau,* the latter of which created some excitement last month when launched by hitting a wall after she had taken to the water in the presence of Hitler. These battleships are, however, steam-driven.

The *Admiral Scheer* is approximately 590 feet long, with a beam of 67.9 feet and a draught of about 19 feet. She has a freeboard of 22 feet and six 28-centimeter (11-inch) guns, three forward and three aft, besides eight 15-centimeter (5.9-inch) guns. There are six torpedo tubes and four 8-8-centimeter (3.6-inch) anti-aircraft guns. Electric welding has been employed in the hull construction to a very considerable degree.

The three twin-screw battleships are the highest-powered oil-engined vessels in the world. The machinery installation in the *Admiral Scheer* consists of eight two-stroke double-acting M.A.N. engines designed to develop a maximum of 7100 B.H.P. and having a normal rating at 6250 B.H.P. of 450 R.P.M., thus representing a total output for service conditions of 50,000 B.H.P. There are two groups of four engines driving two shafts through Vulcan couplings and reducing gear, so that the propeller speed is 250 R.P.M. when the engines are rotating at 450 R.P.M. Each has nine working cylinders with a diameter of 420 millimeters; while the piston stroke is 580 millimeters. The loss in the gearing, shafting and bearings is estimated at about 5½ per cent, so that when developing its maximum power the available shaft horsepower of the machinery is in the neighborhood of 54,000. The engine weight is 17.6 pounds per B.H.P., excluding the gearing, shafting, propeller and air receivers; the total weight, including all engine-room plant and accessories, besides grating, floor plates, etc., is 48.5 pounds, or 22 kilograms per B.H.P.



THE 10,000-TON 26-KNOT 56,000 B.H.P. OIL-ENGINED WARSHIP "ADMIRAL SCHEER."

On each shaft there is a large gearwheel driven by two pinions to port and starboard respectively, each being coupled to one of the propelling motors. The four turbo blowers supplying scavenging air to the main engines are driven by Diesel engines of 2300 B.H.P. running at 425 R.P.M., the blowers being geared up to 3050 R.P.M. Electric current is generated from eight Diesel-driven dynamos each of 250 Kw.

For a very complete description of the engines installed in these battleships, reference may be made to this journal of December, 1931, when the results of trials were also included; from these it appeared that the total consumption, including the power required for scavenging, worked out at 0.385 pounds per B.H.P.-hour, the scavenging air pressure being in the neighborhood of 9 pounds per square inch.

BOOK REVIEWS.

TSUSHIMA. By A. Novikoff-Priboy. Translated by Eden and Cedar Paul. Published by Alfred A. Knopf, New York, N. Y. Price $3.50.

After the Russian naval defeat off the Island of Tsushima in 1905, the surviving Russians were interned by the Japanese until the end of the war. During this period the author had an opportunity of discussing the events of the cruise from the Baltic to the Far East and the events of the battle with survivors from nearly all of the Russian ships. Seldom has an opportunity existed for the collection of such complete information.

Although these notes were destroyed, they were later rewritten from memory but were cached by friends of the writer upon his return to Russia because of his political views. These notes were found in 1933 and the author, after talking again to a number of the survivors, wrote the story of the Second Pacific Squadron which met its fate at Tsushima.

The author was a paymaster's steward on one of the battleships. His training, therefore, hardly fits him for a keen strategical and tactical analysis. Few, if any, of the men who contributed information had any direct access to the officers of the fleet and about the only contact with the command was through surviving signalmen who relayed orders throughout the fleet. The book is written essentially from the viewpoint of the enlisted personnel, many of whom were admittedly illiterate.

Perhaps the strength of the book lies in its lack of a technical approach to the subject. It is the stories of many men who lived through the horror of a naval disaster, and the author has skillfully knit them into a thoroughly readable and moving narrative. Conditions in the Russian fleet during the 18,000-mile cruise to the Far East are vividly described and the experiences and fate of nearly every Russian ship are graphically followed through the battle.

Indeed, invaluable information is to be found for the keen naval analyst.

The impression is given that the chief cause of the defeat was the ineptitude of the Russian command, which extended through the Ministry of Marine directly to the Czarist regime. Beginnings of revolution are already apparent. In considering the merit of the indictment against the Russian Government, it must not be forgotten that this book was written for popular consumption in Russia during the days of new regime. While there can be little doubt of the incompetence of the Russian command, this condition may be somewhat exaggerated. A popular book could hardly charge the Russian people with inherent inferiority and the pre-revolutionary government may, therefore, be unnecessarily pilloried as a scapegoat. After all, the greatest change between the conditions of the disastrous Russo-Japanese war of 1905 and conditions surrounding the present day, center around the change in Russian Government; and the book obviously reaches us with the consent of the present regime.

CUGLE'S TWO-MINUTE AZIMUTHS, VOLUME II. LATITUDES 35° TO 65°, DECLINATION 0° TO 23°, SAME AND CONTRARY NAMES. By CHARLES H. CUGLE. Published by E. P. Dutton & Co., Inc., 300 Fourth Avenue, New York, N. Y. 603 pps. Price $6.00.

Captain Cugle's second volume of azimuth tables, covering latitudes from 35 degrees to 65 degrees, is a compilation of azimuths figured to two-minute interpolations instead of to the usual four-minute spacing. The tables are set in a large, plain type, clearly spaced, and the book is handsomely and strongly bound. It should be a valuable addition to the working library of masters and navigating officers of ships.

DETERIORATION OF STRUCTURES OF TIMBER, METAL AND CONCRETE, EXPOSED TO THE ACTION OF SEA-WATER. Fifteenth Report of the Committee of the Institution of Civil Engineers. Edited by S. M. DIXON, M.A., B.A.I., M.Inst.C.E., and H. J. GROSE, M.C., B.Sc. Published by

His Majesty's Stationery Office, Adastral House, Kingsway, London, W. C. 2. 137 pps. and numerous plates, diagrams and statistical tables. Price 12s 6d, net.

This volume deals with the problem of protecting structures against deterioration in sea water. It constitutes a general survey of the work and observations conducted by the British Institution of Civil Engineers in several different parts of the world since 1920. It is divided into four main sections, as follows:

Preservation of Timber.

Corrosion of Iron and Steel.

Protection of Steel and Iron by means of paint and other preservatives.

Deterioration of Reinforced Concrete.

Under the Notes, in this issue of the JOURNAL, Mr. H. C. Toner, of the Bureau of Engineering, discusses the section dealing with the Corrosion of Iron and Steel.

RADIO AMATEUR'S HANDBOOK, 1937 Edition. Published by the American Radio Relay League, West Hartford, Conn. 544 pps. Price, paper binding, $1.00 postpaid in U. S. A.; elsewhere, $1.25; buckram binding, $2.50 in all countries.

This is the latest edition of the popular and standard manual of amateur radio communication. Many important technical developments during the past year and sweeping changes in operating technique and methods have called for enlargement of the book and rewriting of almost all chapters. Some idea of the extent of the revision may be had from the fact that two hundred new illustrations are included.

Special attention has been given to the new developments in noise silencers for short-wave receivers and to the new technical trends in circuit design. Much new material is added to the wide field of transmitter planning, construction and adjustment. The capabilities of the new tubes are exploited in the radiotelegraph and 'phone transmitter designs presented. Extended space is also given to the ever-important subject of antennas, directional systems and the new ideas in coupling methods are treated in particular

detail. The ultra-high frequencies are discussed also, new and advanced equipment being detailed to illustrate the latest trends in this rapidly-growing field.

As in previous editions, full attention has been given to charts and tables of information for the radio enthusiast; the vacuum tube tables, for example, occupying seventeen pages.

The concluding catalog section, in which a selected list of the leading manufacturers of amateur radio equipment is represented, gives the specifications and prices of standard apparatus for the amateur. The availability of this information within the same covers makes the work a very complete handbook.

TANKER TECHNIQUE, 1700-1936. By B. ORCHARD LISLE. Published by World Tankship Publications, 616, Cecil Chambers, Strand, London, W. C. 2, England, 84 pps. Price, 2 shillings.

This interesting little booklet traces the development of oil-carrying vessels from the *Newchwang Junk* of the early 18th century to the present day large oil tanker. Credit for the first tank steamer is given Ludwig Nobel for the *Zoroaster* (1878) with an oil carrying capacity of 250 tons. Various types of vessels are described in general terms and specialized types of vessels for various liquid services also are covered. The final chapter gives an interesting resumé of tankers in the navies of various countries and includes important commercial tanker tonnage available in war time.

ASSOCIATION NOTES.

OFFICERS FOR 1937.

The following have been elected officers of the Society for the calendar year 1937:

President:

Rear Admiral A. W. Johnson, U. S. Navy.

Secretary-Treasurer:

Commander R. W. Paine, U. S. Navy.

Council:

Captain S. M. Kraus, U. S. Navy.
Captain J. M. Irish, U. S. Navy.
Captain C. C. Ross, U. S. Navy.
Captain H. T. Wright (CC) U. S. Navy.
Commander P. B. Eaton, U. S. Coast Guard.
Mr. J. H. King.
Mr. John F. Nichols.

BANQUET.

The Annual Banquet of the Society will be held at the Willard Hotel, Washington, D. C., on Thursday, 15 April, 1937. Further information relative to this event will be found in the Editor's Forum.

MEMBERSHIP.

The following members have joined the Society since the publication of the last previous JOURNAL:

NAVAL.

Adams, Richard D., Lieutenant, U. S. Navy.
Benson, Roy S., Lieutenant, U. S. Navy.

Bole, John A., Lieutenant, U. S. Navy.
Brady, Edmund E., Jr., Commander (CC) U. S. Navy.
Daspit, L. Randall, Lieutenant, U. S. Navy.
Eckberg, Herbert F., Lieutenant, U. S. Navy.
Johnsen, A. W., Ensign, U. S. Coast Guard.
Kuhl, J. W., Machinist, U. S. Navy.
Midtlyng, Carl R., Lieutenant, U. S. Navy.
Sparks, N. R., Lieutenant, U. S. N. R., 456 East Foster Ave., State College, Pa.
Sullivan, W. D., Lieut. Commander, U. S. N., Ret., Bethlehem Shipbuilding Corporation, Baltimore, Md.
Taft, Philip Henry, Lieutenant, U. S. Navy.
Thiele, E. H., Lieutenant, U. S. Coast Guard.
Wyatt, Joe E., Lieutenant, U. S. Navy.

CIVIL.

Cavanaugh, Raymond F., 37-24 84th St., Jackson Heights, L. I., N. Y.
Hanson, C. F., Irvington, Varnish and Insulator Co., Irvington, N. J.
Nelis, Joseph J., 165 Broadway, New York, N. Y.

ASSOCIATE.

Cruz, Eduardo Barrios, Lieutenant, Chilean Navy.
Lisle, Brian Orchard, care Petroleum World, Bendix Building, Los Angeles, Calif.
Maggio, Cirspino, Standard Oil Company of California, San Francisco, Calif.